DOCUMENT RESUME

ED 210 145 SE 033 513

AUTHOR Mayer, Victor J., Ed.
TITLE Activity Sourcebook for Earth Science. Science Education Information Report.
INSTITUTION ERIC Clearinghouse for Science, Mathematics, and Environmental Education, Columbus, Ohio.
SPONS AGENCY National Inst. of Education (ED), Washington, D.C.
PUB DATE Dec 80
CONTRACT 400-78-0004
NOTE 249p.
AVAILABLE FROM Information Reference Center (ERIC/IRC), The Ohio State Univ., 1200 Chambers Rd., 3rd Floor, Columbus, OH 43212 ($7.75).

EDRS PRICE MF01/PC10 Plus Postage.
DESCRIPTORS Astronomy; Climate; *Earth Science; *Field Studies; Geology; *Meteorology; Oceanography; Physical Geography; *Science Activities; Science Education; Secondary Education; *Secondary School Science; Seismology; Space Sciences
IDENTIFIERS *Plate Tectonics; Space Photography

ABSTRACT

Designed to provide teachers of earth science with activities and information that will assist them in keeping their curricula up to date, this publication contains activities grouped into six chapters. Chapter titles are: (1) Weather and Climate, (2) Oceans, (3) The Earth and Its Surface, (4) Plate Tectonics, (5) Uses of Space Photography, and (6) Space. Each activity has been set in the same general format (introduction, objectives, materials, procedure, and, for some activities, review or summary questions). Some activities are new; others have been standard for years but are located in publications no longer readily available to teachers. (PB)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED210145

U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)
X This document has been reproduced as received from the person or organization originating it.
☐ Minor changes have been made to improve reproduction quality.
• Points of view or opinions stated in this document do not necessarily represent official NIE position or policy.

SCIENCE EDUCATION INFORMATION REPORT

THE ERIC SCIENCE, MATHEMATICS AND ENVIRONMENTAL EDUCATION CLEARINGHOUSE
in cooperation with
Center for Science and Mathematics Education
The Ohio State University

SE 033 913

Compiled and Edited

by

Victor J. Mayer

Science and Mathematics Education
The Ohio State University
Columbus, Ohio 43210

ACTIVITY SOURCEBOOK

for

EARTH SCIENCE

Published by

ERIC Clearinghouse for Science, Mathematics
and Environmental Education
The Ohio State University
College of Education
1200 Chambers Road, Third Floor
Columbus, Ohio 43212

December, 1980

FOREWORD

The ERIC Clearinghouse for Science, Mathematics, and Environmental Education is pleased to cooperate with the National Association for Geology Teachers in producing this activity sourcebook. We believe that this sourcebook will be of value to earth science teachers wishing to incorporate recent developments into their classes.

We invite your comments and suggestions for future publications.

Stanley L. Helgeson
Associate Director
Science Education
ERIC/SMEAC

Patricia E. Blosser
Faculty Research Associate
Science Education
ERIC/SMEAC

This publication was prepared with funding from the National Institute of Education, U.S. Department of Education under contract no. 400-78-0004. The opinions expressed in this report do not necessarily reflect the positions or policies of NIE or U.S. Department of Education.

INTRODUCTION

Teachers of earth science are responsible for conveying information from several of the most exciting and rapidly developing fields of science. Space and deep sea explorations have opened up dramatically new fields of evidence over the past two decades resulting in a revolution in the theoretical and conceptual structures of the disciplines of geology, oceanography and planetary studies. Recent events such as the explosion of Mount St. Helens have helped to create a public interest and fascination with the field of earth science. Dramatic weather occurrences such as tornadoes and the severe winters experienced by the Northeast in the latter 70's continue to focus public attention on the study of weather and climate.

Geology has undergone a dramatic revolution in the last fifteen years. Data being acquired worldwide has resulted in the acceptance of a new theory accounting for the development of ocean basins and continents, and events such as volcanism and earthquakes. The National Association of Geology Teachers (NAGT) in responding to the challenge posed by the rapid acceptance of this theory obtained funding from the National Science Foundation to develop teaching materials that would assist secondary school teachers in relating the components and evolving nature of the theory to their students. Over a three-year period of time the Crustal Evolution Education Project developed 64 modules; 32 of which have now been published by Ward's Natural Science Establishment, Inc., P. O. Box 1712, Rochester, New York 14603. Information regarding the purchase of these modules can be obtained from Ward's. They have also published, and will send free with any order, a summary of the national evaluation program conducted of the CEEP materials.

This book has been prepared by (NAGT) in cooperation with the ERIC Clearinghouse for Science, Mathematics, and Environmental Education to bring to secondary school teachers of earth science, general science and biology, activities and information that will assist them in keeping their curricula up to date and in satisfying the curiosity of their students about an exciting and growing field of science. A major responsibility of teachers is to present their students with the most modern view of science and with information that represents science's most current understanding of the way the world works. This book is a further effort by NAGT to assist teachers in meeting that responsibility.

An entire chapter has been devoted to the theory of plate tectonics. Most of the investigations in that chapter were developed by the Crustal Evolution Education Project and published in the Association's Journal of Geological Education.

Other activities were written expressly for this publication, such as one on the eruption of Mt. St. Helens developed by Robert

Christman of Western Washington University. One chapter has been devoted to investigations based upon space and satellite imagery to allow teachers to take advantage of this spectacular new source of data. Most of them were developed by the National Aeronautics and Space Administration. Many of the activities, including two on the uses of space imagery, were written by teachers in workshops and have not been published previously.

Although most of the activities have been developed recently and represent the most modern advances in the earth sciences, several good old standbys have been included that have been published in a variety of sources which are no longer readily available. In addition, several activities dealing with basic concepts in the earth sciences but presenting them in new and novel manners have been included.

We hope that teachers will find this a valuable publication in their efforts to keep classes exciting and the content modern.

Using the Activities

Most of the activities have been presented in considerable detail. Teacher suggestions and answers to questions are often included in italicized type. The authors have attempted to provide all of the information necessary for the teacher to conduct the activity. Most can be used as they appear in the book. However, many teachers may want to simplify an activity or merely use the information in a class discussion or lab. We hope the format facilitates their use in many different ways.

The activities differ in difficulty and complexity to provide for the variety of ability levels of students. Many are intended for the talented student, who is often ignored in the development of teaching materials. The number in parenthesis following the title of the activity in the table of contents indicates the estimated difficulty level: (1) relatively easy; (2) average difficulty; and (3) activity intended for the more able student.

Victor J. Mayer
December, 1980

EDITOR

Victor J. Mayer

The Ohio State University

CONTRIBUTING EDITORS

Robert A Champlin
Fitchburg State College

Robert A. Christman
Western Washington University

Gerald H. Krockover
Purdue University

ACTIVITY AUTHORS

Randy Allen
Circleville (Ohio) Public Schools

Ronald E. Armstrong
South Glen Falls Middle School, New York

Myrl Beck
Western Washington University

Glen Caple
Fitchburg (Massachusetts) Public Schools

Gaylen Carlson
California State University, Fullerton

James A. Coe
The Ohio State University

James W. Collinson
The Ohio State University

Casper Cronk
Phillips Petroleum Company

David H. Elliot
Institute of Polar Studies

Rosanne W. Fortner
The Ohio State University

Paul J. Fox
State University of New York at Albany

Garry Jones
Western Washington University

Beth A. Kennedy
Newark (Ohio) Public Schools

Gene Lene
University of Texas at Austin

Paul D. Lowman, Jr.
Goodard Space Flight Center

R. Jon McQuillan
Upper Arlington (Ohio) Public Schools

Richard Passero
Western Michigan State University

Ronald F. Pauline
Mt. Union (Pennsylvania) Public Schools

Richard Powell
Sammamish High School, Washington

Thomas J. Rillo
Glassboro State College

Keith M. Schlarb
Worthington (Ohio) Public Schools

Maurice L. Schwartz
Western Washington University

William N. Green
Crown Point (Indiana) Public Schools

Craig Huff
Huntington Beach High School, California

Larry Johnson
Cascade Junior High School, Washington

Douglas Smith
University of Texas at Austin

Tracy Vallier
United States Geological Survey

Bill White
Texas Bureau of Economic Geology

Kathleen Wilkes
Fairfax County (Virginia) Public Schools

CRUSTAL EVOLUTION EDUCATION PROJECT

Edward C. Stoever, Jr., Project Director

Southwest Missouri State University

Warren E. Yasso
Director, New York
Development Center
Teachers College,
Columbia University

Rolland B. Bartholomew
Director, Texas
Development Center
University of Texas
at Austin

Robert W. Ridky
Director, Maryland
Development Center
University of Maryland

Arie Korporaal
Director, California
Development Center
Superintendents Office,
Los Angeles County

Victor J. Mayer
Director, Ohio
Development Center
The Ohio State University

Maurice Schwartz
Director, Washington
Development Center
Western Washington State
University

Victor J. Mayer, Director of Evaluation
The Ohio State University

TABLE OF CONTENTS

CHAPTER 1 - WEATHER AND CLIMATE

Matching Wits With the Weatherman (2)* 3

Investigating Snow (2) 7

Clouds and Rain (2) 9

Cloud Covering and Its Effect on Available Incident Solar Radiation (2) 13

Blue Skies and Red Sunsets (2) 17

Mother Earth's Greenhouse (2) 21

CHAPTER 2 - OCEANS

Bathymetric Analysis (2) 31

Ocean Currents (2) 35

Density Currents (1) 43

The Types of Tide and the Tide Curve (3) 47

Coastal Processes and Erosion (1) 53

Microfossils and Ancient Ocean Temperatures (3) 61

CHAPTER 3 - THE EARTH AND ITS SURFACE

Exploring Old Cemeteries (2) 71

Rocks From Layered Sediments (1) 73

Panning for Gold (1) 75

Classifying Fudge and Rocks (1) 77

The Ice Age Puzzle (3) 83

Using a Sandwich to Understand Superposition (1) 89

Using Seismology to Learn About the Earth (3) 99

Travel Time: Earthquakes and Horses (2) 105

CHAPTER 3 - THE EARTH AND ITS SURFACE (cont'd)

Epicenters of the 1964 Alaskan Earthquake (3) 115

Density and What It Can Tell Us About the Structure of the Earth (3) 123

Ashfall in Washington: Courtesy of Mount St. Helens (2) . . 129

CHAPTER 4 - PLATE TECTONICS

Movement Along the San Andreas Fault (2) 137

Imaginary Continents: A Geologic Puzzle (2) 141

Earthquakes and Plate Boundaries (3) 147

Which Way is North? (2) 155

Sea-Floor Spreading and Transform Faults (3) 165

How Fast is the Ocean Floor Moving? (3) 173

Fossils as Clues to Ancient Continents (3) 181

Plate Tectonics and Evolution (2) 191

Drifting Volcanoes (2) 197

CHAPTER 5 - USES OF SPACE PHOTOGRAPHY

Resources 207

Using Landsat Imagery to Study Earth's Surface Features (2). 209

Assessing Our Impact Upon the Environment by Using Landsat Images (2) 215

Africa, the Splitting of a Continent (3) 219

Plate Tectonics in the Solar System: Evidence from Space Photography (3) 225

CHAPTER 6 - SPACE

Lost on the Moon: A Decision Making Problem (1) 231

Observation of Sunspots (1) 235

CHAPTER 6 - SPACE (cont'd)

Parallax Effect (3) 241

Star Color and Composition (2) 251

Plotting and H-R Diagram (2) 255

*Number in parentheses indicate estimated difficulty level.

CHAPTER I

WEATHER AND CLIMATE

Matching Wits with the Weatherman

by
Robert A. Champlin

Introduction

There are many factors that a meteorologist takes into account before making a weather prediction. Studies show that they make accurate forecasts at least 85% of the time, even though it may not seem so. People only seem to notice when the meteorologist is wrong!

You can make an accurate weather forecast more than 50 percent of the time with just two types of accurate information: wind direction and speed and the condition of the barometer (which measures air pressure).

In this activity you will have a chance to make weather predictions and to match predictions with the local meteorologist.

Objectives

When you have completed this activity you should be able to:

1. Make accurate short range weather forecasts using general descriptive terms.
2. Calculate percentages.
3. Keep a careful record of weather predictions and outcomes for an extended period.

Materials

A chart entitled WIND AND PRESSURE READINGS
A notebook for keeping records

Procedures

Your teacher will show you how to read the WIND AND PRESSURE chart. Decide on a source of information to obtain data concerning barometric pressure and wind speed and direction. Your teacher may suggest a good source.

Another very important part of the activity is for you to select your "favorite weather announcer" and to keep track of his/her forecasts as well as your own. Do this for a ten-day period. (Ten school days is fine.) Keep in mind that your

prediction is dependable for up to three or four hours. The weather announcer may be making a 24 hour forecast. So, when you are comparing your prediction with what actually happens, use only the part of the weather announcer's forecast that is for the same time period as yours.

Keep your data on a chart or in a notebook using the following headings: Date and Time, Wind Speed and Direction, Barometric Pressure, My Three Hour Prediction, Weather Announcer's Three Hour Prediction, Weather for Three Hour Period.

1. How many predictions did you make accurately?

2. What was your percentage of accuracy? The weatherman's?

3. Write a statement about the usefulness of wind and barometer readings in making accurate weather forecasts.

4. What information does a meteorologist have that enables him/her to make extended forecasts (24 hours or longer)?

It is very important for the students to use reliable up-to-the-minute data in making their predictions. Newspapers are not good sources. If your school does not have a weather station, a call to the local television station or airport may be the best alternative. Emphasize that in comparing predictions the student's forecast must cover the same time period as the weather announcer's.

One school in New England compared its forecasts with those of several area meteorologists over a period of two months, then sent the meteorologists a "report card grade."

WIND AND PRESSURE READINGS

Wind Direction	Barometer	Rising	Steady	Falling
S	above 30.50	B	B	F
	30.01-30.50	A	B	F
	29.71-30.00	A	A	G
	29.41-29.70	G	G	H
	below 29.01	E	E	H
S.West	above 30.50	B	B	F
	30.01-30.50	A	B	F
	29.71-30.00	C	A	G
	29.41-29.70	D	E	E
	below 29.41	D	E	E
West	above 30.50	B	B	B
	30.01-30.50	A	A	F
	29.71-30.00	C	A	G
	29.41-29.70	C	C	E
	29.01-29.40	C	D	E
	below 29.01	D	E	E
N.West	above 30.50	A	A	B
	30.01-30.50	C	A	F
	29.71-30.00	C	A	G
	29.41-29.70	C	C	E
	29.01-29.40	C	D	E
	below 29.01	D	E	E
North	above 30.50	A	A	F
	30.01-30.50	C	A	F
	29.71-30.00	C	A	H
	29.41-29.70	C	D	H
	29.01-29.40	C	D	E
	below 29.01	D	E	H
N.East	above 30.50	A	A	F
	30.01-30.50	C	A	F
	29.71-30.00	A	A	G
	29.41-29.70	C	H	G
	below 29.41	D	H	H
East	above 30.50	A	A	F
	30.01-30.50	A	A	F
	29.71-30.00	A	A	G
	29.41-29.70	G	G	G
	below 29.41	H	H	H
S.East	above 30.50	A	B	F
	30.01-30.50	A	A	F
	29.71-30.00	A	A	G
	29.41-29.70	G	G	G
	below 29.01	H	H	H

A. Fair weather, not much change in temperature
B. Fair and Warmer
C. Fair becoming cooler, colder in winter
D. Clearing within 12 hours
E. Rain or showers, clearing and colder in 12 hours
F. Increasing cloudiness followed by rain
G. Rain or showers
H. Rain or showers and colder

Investigating Snow

by
Gerald H. Krockover

Introduction

Snow provides an opportunity for students to observe, infer, and measure its properties. It is readily available in many regions and it sometimes comes in huge quantities.

Objectives

After you have completed these activities, you should be able to:

1. Record observations of snow and its effects upon your environment.
2. Calculate the water content of snow
3. Measure snow temperatures, pH and oxygen content.

Materials

Meter Stick (or Yard Stick)
Hach dissolved oxygen and pH test kits
Coffee Can
Plastic Sandwich Bags
Thermometers
Snow Shovel

Procedure

Locate a suitable site for students to conduct these activities.

1. Go outside. Observe and record your observations about the influence of snow upon plants, animals, air, and water. Look for evidence of animal habitats in the snow.
2. Collect the information needed to complete Table One: Computing the Water Content of Snow.
3. Prepare a data table and record the air temperature and the snow temperature at 1/3 and 2/3 depth. Record the ground temperature.
4. Determine the dissolved oxygen content and pH of some melted snow using the procedures described in your test kit.

5. Compact snow into a coffee can and find out if compacted snow contains more water after it has melted than snow that has not been compacted. Place snow samples in plastic bags for melting and for pH and dissolved oxygen testing.

Review Questions

1. What did you observe about the snow?
2. Observe the types of trees that are most affected by the snow.
3. Observe the effect that the snow has upon a lake or stream.
4. What animal habitats did you find?
5. How are animals affected by snow?
6. Under what conditions would we obtain different results for the water content, pH, and dissolved oxygen readings for snow?
7. Is snow good or bad? Why did you say one or the other?

TABLE ONE

COMPUTING THE WATER CONTENT OF SNOW

Instructions for collecting and recording water equivalents of snow.

a. Measure snow depth in six random locations on the site. Be sure to select areas where there is little drifting and no man-made tracks. Record the depth at each location, compute the total and divide by the number of measurements to compute <u>average snow depth</u>.

$$\frac{\text{Sum of measurements}}{\text{No. of measurements}} \quad \frac{\qquad}{6} = \qquad \text{Average snow depth in inches}$$

<u>An Acre-Foot of Water</u>

An acre-foot is one acre (43560 sq ft) of water, 1 foot deep and contains 325,000 gallons of H_2O or an acre inch equals approximately 27,000 gallons of H_2O.

b. Find the water volume content of the snow per acre.

$$\frac{\text{(average depth of snow)}}{} \div \frac{10}{\text{(inches)*}} = \frac{}{\text{(No. of inches of } H_2O\text{)}}$$

*For our problem we will use the H_2O equivalent of snow 1:10--1 inch of H_2O equals 10 inches of snow.

c. Amount of H_2O on site, if it all could be captured.

$$\frac{}{\text{(No. of inches of } H_2O\text{)}} \times \frac{27{,}000}{\text{(H_2O in 1 acre-inch)}} \times \frac{}{\text{(acreage)**}} = \frac{}{\text{(gals. of } H_2O \text{ on site)}}$$

**Acreage or fractions of acre information should be made available to group.

d. Find how many people could be supported by H_2O equivalent of snow on the site.

$$\frac{}{\text{(Gals. of } H_2O \text{ on site)}} \div \frac{200}{\text{(Avg. daily } H_2O \text{ needs)}} = \frac{}{\text{(People supported)}}$$

Clouds and Rain

Adapted from an activity developed by the
Earth Science Curriculum Project,
Investigating the Earth,
Boulder, Colorado, 1965

by
Victor J. Mayer

Introduction

You have seen many clear or cloudless days, but have you ever stopped to wonder why the day was clear? There are no clouds in the sky, and yet an airplane pilot flying at low altitudes reports the air as bumpy. On another day cumulus clouds may start to form but never get very big. What are the conditions that restrict the growth of the cumulus clouds and sometimes prevent their formation, even though the day may be very warm?

Do you know what convection is? The smoke from a bonfire is carried upward by convection. When you observe fair-weather cumulus clouds you can actually see that convection of moist air stops at the top of the cloud. A rising bubble of heated air will continue to rise as long as its temperature remains warmer than the surrounding air. If the air at higher elevations is cold enough, warm air will continue to rise until condensation occurs and a cumulus cloud is formed. The cloud top will then tend to grow upward even faster because condensation releases hidden or latent heat into the rising air bubble. It may even continue to rise until a thunderstorm is formed and rain falls from the cloud. Why doesn't the base of the cloud keep going up like the top--as if the cloud were a balloon?

In this activity you will examine how the humidity (the amount of water vapor in the air) can be measured by condensation onto a cold object, and how the level where cumulus clouds form can be calculated from the temperature and the dewpoint temperature.

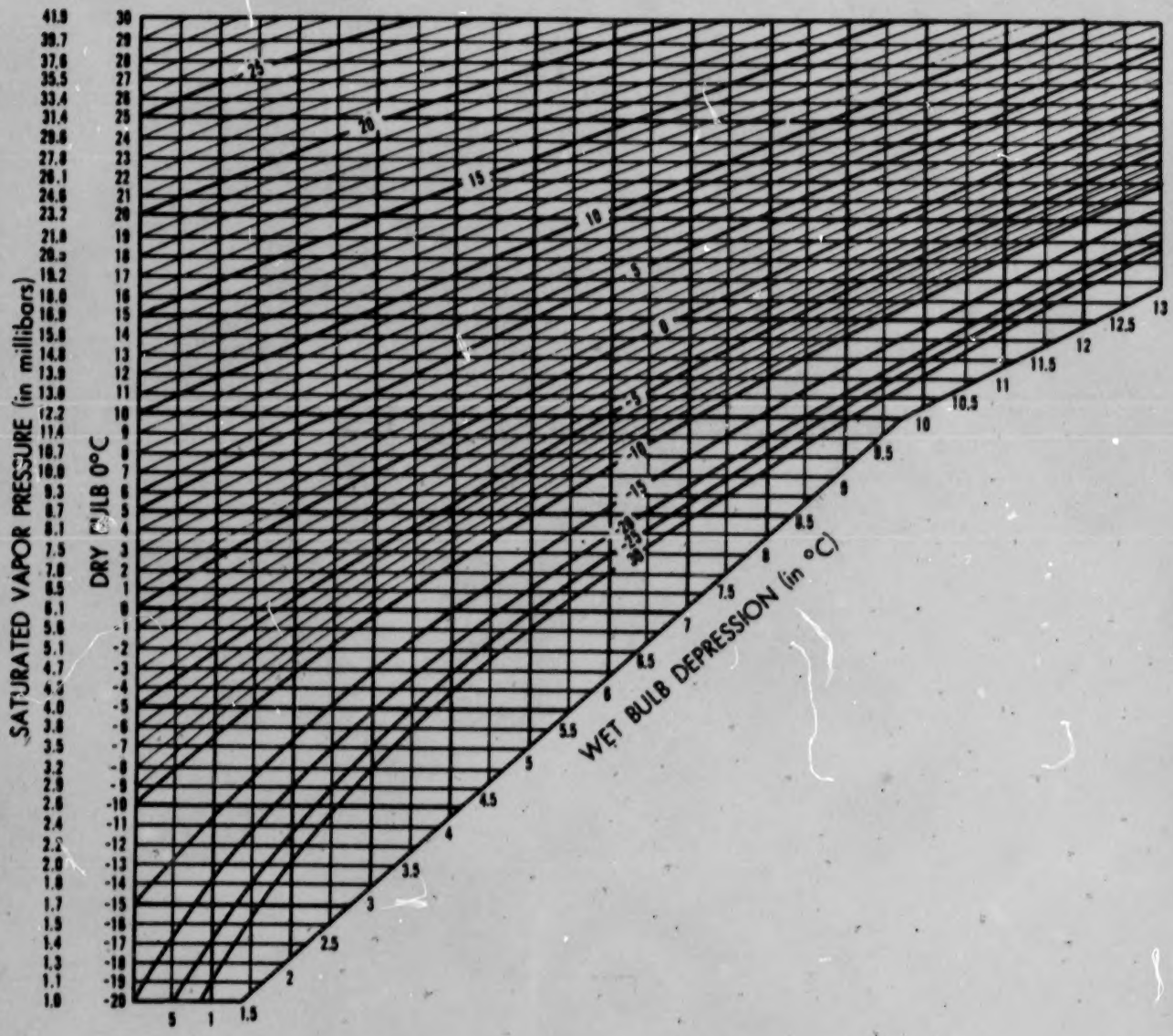
Objectives

When you have completed this activity you will be able to:

1. Determine dewpoints.
2. Determine the elevation at which cumulus clouds will form.
3. Explain the circumstances that will cause moisture in air to condense.

Materials

A small shiny metal can
Popsicle sticks, tongue depressors, or lead pencils for stirrers
Crushed ice
Psychrometer
Dewpoint temperature chart



20

Procedure

Part A. The Dewpoint Temperature.

1. Fill a can about half full of water, put the thermometer in it, and drop in ice a little at a time. Stir gently with a small stick or pencil to melt the ice and cool the water. The temperature at which the condensation begins to form is called the dewpoint temperature.

2. Read the thermometer when the dew first appears and write down the value.

3. Remove any remaining ice and let the can warm up until the condensation disappears.

4. Then add more ice a little at a time and let the can cool slowly until the condensation reappears. Read the temperature again. Was the temperature at which condensation formed the same as before?

6. Repeat the procedure and record the temperature again. The highest temperature at which condensation occurs is probably the best value for the dewpoint temperature. Why? *Note:* The dewpoint temperature is a direct indication of the amount of water vapor in the air; that is, a given dewpoint temperature corresponds to a certain number of water vapor molecules present in a given volume of air or to a specific vapor pressure due to water vapor molecules present.

6. Compare your dewpoint temperature with others in the class. When you are satisfied that you have obtained the representative dewpoint temperature of the room, record your answer.

7. Take a psychrometer reading both indoors and out. Convert the psychrometer readings to dewpoint from the Dewpoint Temperature Chart.

8. How do the dewpoint temperatures indoors and outdoors compare? How do the dewpoint temperatures taken with psychrometer and the dewpoint hygrometer (the shiny can) compare? Is there a difference between the indoor dewpoint and the outdoor dewpoint?

Part B. Convective Condensation Level.

You will now attempt to calculate or predict the base height of cumulus clouds, using the dewpoint temperature and the maximum temperature. If the day does not look as if it will have cumulus clouds, the teacher may give you some data from the weather watch

taken on a day when there were cumulus clouds. You have already determined the outdoor dewpoint temperature. If cumulus clouds are not expected until afternoon and you are in a morning class, you will have to assume that the dewpoint temperature will not change very much. Is this assumption a good one? The other bit of information that you will need is the maximum air temperature your area will have for the day. Again, if this is a morning class, the maximum temperature will have to be that predicted.

1. What effect does air convection have on the heating of the air near the ground?

2. Why does the temperature rise rather quickly in the morning, and then quite slowly as the maximum temperature is approached?

Measurements have shown that when air rises (and expands), it cools at 10° C per kilometer. This rate of decrease in temperature as the air rises (pressure falls) is called dry adiabatic lapse rate. It is called dry because it does not involve condensation, and the word adiabatic means that no heat is gained or lost from the surroundings (that the cooling is due only to decrease in pressure).

3. Starting with today's maximum air temperature, what is the temperature at 0.1 kilometer above the ground? at 0.2 kilometer?

Measurements have shown that the dewpoint temperature also decreases in a rising air bubble. The dewpoint decreases 1.7° C per kilometer.

4. Starting with your dewpoint reading (surface reading), what is the dewpoint temperature at 0.1 kilometer above the ground surface? at 0.2 kilometer?

5. Continue the calculations for each 0.1 kilometer for both temperature and dewpoint temperature until you find the altitude where the temperature and the dewpoint temperature become equal. At what altitude does this occur?

6. From your knowledge of what the dewpoint temperature represents, what happens at this altitude?

Cloud Covering and Its Effect on Available Incident Solar Radiation

Adapted from Solar Energy Project Activities
U.S. Department of Energy
Stock Number 061-000-00232-4
January, 1979

by
Gerald H. Krockover

Introduction

This activity will familiarize you with the solarimeter and the effect that cloud covering has on the sun's radiation received at ground level. You will observe cloud cover, make solarimeter readings, record the data, plot a graph and interpret the information obtained.

Objectives

After you have completed this activity you should be able to:

1. Operate a solarimeter.
2. Construct a graph from the data.
3. Draw inferences from the data.
4. Demonstrate an understanding of the effect of cloud covering on the available incident solar radiation.

Materials

Solarimeter or photographic light meter
Graph paper and pencil

Procedure

1. In order to have valid results you must take accurate data and notes. Prepare a data sheet to include the following: observer's name, the location, date, general cloud covering the time each meter reading is taken, the meter readings, and the cloud cover between the sun and the meter at the moment the reading is made.
2. Data from one class period will be sufficient if the clouds are spaced so that both direct and overcast (indirect) sun-

light are observed. Additional readings can be made over a longer period for even better results. The solarimeter should be located away from shadows and bright objects. It may be best to have the meter at or close to eye level. The solar cell must be horizontal. The observer should not interfere with the light.

3. Using the meter readings on the vertical scale and the time on the horizontal scale plot the data on graph paper. Determine the relationship between the cloud cover and the meter reading.

Using the data collected, you should be able to find a relationship between the incident radiation measured and the cloud cover. Data may be collected over a longer period of time such as a full day, week or more.

CAUTION: NEVER LOOK DIRECTLY AT THE SUN!!

Review Questions

1. What is the maximum reading recorded?

2. What was the cloud cover at the time of the maximum reading?

3. What was the lowest reading recorded?

4. What was the cloud cover at the time of the lowest reading?

5. If heavy clouds came in front of the sun, why didn't (wouldn't) the reading go to zero?

There is indirect light from the sky.

6. Calculate the percentage of time the readings were below the 50% level.

7. Calculate one half (50%) of the maximum reading.

8. Calculate the percentage of time the readings were below the 50% level.

9. In general, what is the relationship between cloud cover and the amount of solar radiation striking your meter?

10. Do you feel that there is enough available sunlight in your area for use in heating homes or for other solar energy uses? (Do you have enough data to make a good estimate?)

11. Was this type of day typical for your location?

Typical Results

Time	*Meter Reading*	*Remarks*
10:00 a.m.	*60*	*Clear*
10:05	*60*	*Clear*
10:10	*41*	*Cloud edge over sun*
10:15	*25*	*Heavy cloud over sun*
10:20	*30*	*Heavy cloud over sun*
10:25	*28*	*Heavy cloud over sun*
10:30	*52*	*Thin cloud over sun*
10:35	*62*	*Clear*
10:40	*62*	*Clear*
10:45	*45*	*Thin cloud over sun*

Blue Skies and Red Sunsets

by
James A. Coe, 1975

Introduction

The scattering effect of very small particles in the air can be compared with the effect of passing a beam of light through water containing a few drops of milk.

Objectives

When you have completed this activity you should be able to:

1. Explain why sunsets are red whereas the sky overhead is blue.

2. Explain why space is black to astronauts traveling there.

3. Identify surfaces that reflect light and those that absorb light.

Materials

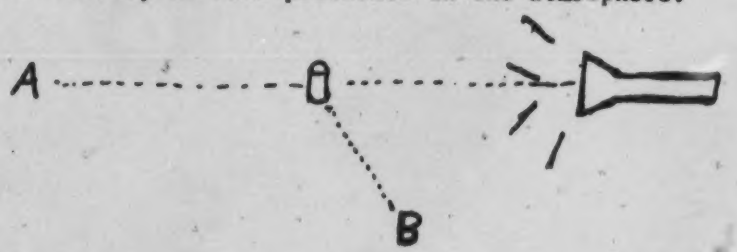
Vial Dropper
One ml of milk
Access to a narrow beam of light - a flashlight with a cardboard mask is suitable
Light meter (optional)

Procedure

A darkened corner of the room is best for this activity.

1. Add about eight drops of milk to the vial. Fill the vial with water and shake it.

2. Arrange for the beam of light to shine into the vial as in the diagram below. The suspended particles of milk act in much the same way as fine particles in the atmosphere.



3. What difference in color do you see when looking at the beam from B as compared with A?

This color difference comes about because blue light is scattered more readily than red. In the atmosphere, particles of dust and water vapor, for example, cause this reflection and scattering effect.

4. Explain why at sunset the sky overhead appears blue, but nearer the horizon it is orange or red.

When astronauts leave the Earth's atmosphere and look into space, space looks black.

5. Explain why this happens.

Depending on conditions in the atmosphere, as little as one half of the energy entering the atmosphere may reach the Earth's surface. A number of things may happen to this energy. Some may be reflected.

6. What kind of surface would you expect to reflect the most radiant energy?

The amount of light energy reflected from various surfaces can be measured by using a light meter. This is an instrument which transforms light energy into electrical energy. A needle moving across a scale compares the amount of light entering the meter from various sources.

7. If there is a light meter available, use it to compare various surfaces. The meter is a delicate instrument. Do not point it directly at the Sun. In the space below record the meter readings for light reflected from various surfaces.

Note that poor reflectors are good absorbers of radiation.

Some energy may cause heating of the Earth. This effect to some extent will depend on the type of surface.

8. Suggest the kinds of surfaces likely to heat most rapidly.

Some energy may be absorbed to bring about chemical changes. Substances, whether simple or complex, are built up from atoms. The atoms are linked or attached to each other by chemical bonds. During a chemical change bonds are broken and different atoms may become linked together, forming new substances. Sometimes the energy of light - for example a pulse with a particular energy - is sufficient to break a bond to enable new links to form.

Mother Earth's Greenhouse

by
Robert A. Christman, 1980

Introduction

Do you know what the "greenhouse effect" is? Do you know that the Earth and its atmosphere can be thought of as a huge greenhouse? Scientists are concerned that the people of the Earth are changing the "glass" of the Earth's greenhouse. Let's see what we can learn about this "glass."

Objectives

Upon completion of this activity you should be able to:

1. Describe the "greenhouse effect."
2. Tell how its effect varies with the kind of "glass."
3. Explain how the Earth's balance of heat might be changed.

Materials

Thermometers - one for each team
Variety of glass and plastic bottles
Baking soda
Vinegar
Matches
Beaker
Watch
Paper and Pencil

Procedure

Part A

First let's consider some important ideas related to the greenhouse effect. Much of the energy from the sun comes as waves. One particular group of wave lengths we know as visible light. These vary from violet light with shorter wave lengths to red light with longer wave lengths. When all the wave lengths of the visible light spectrum occur together, we observe white light. Waves shorter than violet light are ultraviolet, X-rays, gamma waves and cosmic waves. Waves longer than red light are infrared rays, "radar" waves and radio and long electrical waves.

Much of the solar radiation which reaches earth is in the form of visible light and shorter infrared rays. When these shorter rays strike other materials, such as your skin, the ground, and leaves, they are converted to longer wave lengths. You recognize these as heat. Part of this heat is absorbed and part is radiated back into the air. Have you noticed how a sunny spot on a rug or table is warmer than the surrounding air or even the glass of the window pane?

Shorter rays can pass freely through glass. However, the longer heat waves cannot pass as freely through the glass. These are trapped. This is one reason why the air in a greenhouse on a sunny day becomes warmer than the air outside.

Another factor relates to the fact that the warm air in a greenhouse cannot escape by rising, because it's confined. This factor does not apply to the earth. For this reason, it has been suggested that a better description for the earth is "atmospheric effect" than "greenhouse effect."

In this activity we will find out how much heat is trapped inside various kinds of transparent containers. Let's see if we can discover what factors control the amount of heat which will be trapped.

Various kinds of sealed transparent containers will be put in the sun. The change in temperature will be measured as the long waves are trapped. What we want to find out is how effective different kinds of materials are in trapping the long waves. How does the shape of the container effect the amount of heat trapped? What other factors are important?

The conditions of the experiment must be controlled. If the temperature rises more in a large green bottle than in a small clear bottle, we will not know whether this was caused by the color of the glass or the size of the bottle.

1. What kinds of different factors do you want to measure? What kinds of things do you need? Write your answer here:

If enough thermometers are available, let the students work in small groups. Let them design their experiments but be sure different groups are testing different things. You might plan the experiment one day and give the students a day to collect the various kinds of containers from their homes.

The following kinds of pairs of bottles might be used:

Size: large vs small clear glass bottles

Color: clear vs colored glass

Material: plastic vs glass bottles

Thickness: thin light-weight plastic vs thick plastic bottles

Gas content: air vs CO_2

Solid content: empty bottle vs one with material to aid conversion of ray

You may have to make some suggestions because students probably will not think of the CO_2 experiment. (A method for obtaining a bottle of CO_2 is given at the end of this activity.) Remind the students that in selecting the containers that the opening must be large enough for the thermometer. All must have caps or corks.

2. Prepare the bottles for the experiment by placing the thermometers inside each bottle being used. Check that all start out at the same temperature. This is also a check on whether the thermometers are calibrated the same. Put the caps or corks on the bottles.

3. Place the bottles in the sun and record the rise in temperature inside the bottles at regular intervals. Someone also should be measuring the change in temperature of the air outside the bottles. Measurements should be made every ten or fifteen minutes until the temperatures no longer change.

This activity works well outside in the sun light. If done inside with light that has already passed through the glass of a window pane, the increase of temperatures inside the bottles will be less, by about 10-15° C. Most of the heating will take place in the first 30 minutes. However, the students may want to make measurements for an hour, or more, to see what happens.

4. Put your data in a form which can be easily understood. You may want to express your findings in graph form. Show the rise in temperatures in your two bottles and in the outside air as a function of time.

5. Why did the temperature reach a certain level and then go no higher? Why does the temperature inside the bottle not continue to rise after a certain temperature is reached?

After a certain temperature is reached, the amount of heat which escapes equals the amount of accumulation. The temperature will remain constant. Also if the experiment is done after 12:00 noon (sun time) the amount of energy from the sun is becoming progressively less with time.

6. What did you conclude about your experiment?

Answers will vary depending on what each group measured. Most bottles will show an increase of 10-15°C.

7. By class discussion, answer the following questions:

a. What produced the greatest temperature change?

The bottle with CO_2 should be 2-3°C hotter than those with air.

b. What produced the least temperature change?

The bottle with thin plastic

c. Did the size of the bottle make a difference?

The size does not seem to be a factor. Temperature rose in a big bottle as fast as it did in a small one.

d. Did it make a difference whether the glass was clear or colored?

The color of the glass did not seem to make much difference. In one experiment a dark green bottle seemed to become slightly hotter.

e. Did the bottle with something inside of it make a difference in the heating?

It may make a small difference. One bottle with yellow paper on the side away from the sun became slightly hotter. This might be because the paper prevented any short waves from passing completely through the bottle.

Although the earth is not enclosed by glass or plastic, the CO_2 and H_2O in the atmosphere act as a glass "sphere." These two gases do not transmit the long wave lengths of heat being radiated from the earth. They act as a "cover" to keep the heat from escaping into space.

8. What do you suppose might happen if the amount of CO_2 in the atmosphere became greater?

   More of the heat would be trapped and the earth could become progressively hotter.

The amount of CO_2 in the atmosphere is known to have increased during the last 100 years. It is believed that the amount of CO_2 in the atmosphere is increasing at the present time. Some scientists are concerned that when the amount reaches some critical amount, the earth might become decidedly warmer. This could cause some serious problems. However, it is possible that other unknown factors affect the question. For example, calculations show that the amount of CO_2 being produced seems to be greater than the amount which is accumulating. Scientists are not certain where the CO_2 is going. They believe that it is being taken up by the ocean.

9. What has the human population done to cause the increase in the amount of CO_2 being produced on a world-wide basis?

   Burning coal, wood, and gasoline produces CO_2. The population has been increasing in size during the past 100 years and more fuel is being burned.

   Cutting down large areas of trees means that less CO_2 is being converted to O_2. The elimination of tropical areas of lush vegetation could result in an increase in the CO_2.

Part B

Several methods may be used to obtain a bottle of CO_2. If dry ice or CO_2 capsules are used, it is necessary to bring the collected gas to room temperature. If a chemical reaction is used, it is necessary to remove the excess solids and water vapor from the bottle.

The following method of obtaining the CO_2 by reaction of acid with baking soda is recommended. This method also makes an interesting classroom activity.

1. Put some baking soda in a beaker or other container.

2. Secure the beaker on a ring stand so that the beaker is tipped about 45°. (See figure)

3. Place a collecting bottle below as if the bottle was going to collect whatever spills out of the beaker.

4. Pour acid into the beaker. Because of the odd angle, you may want to use a funnel. The acid may be vinegar or dilute HCl. It is not necessary to use concentrated acid.

5. Observe the CO_2 being produced by the foaming.

Explain to the class the CO_2 is heavier than air. As the beaker fills up with CO_2, the invisible gas spills out over the lip and down into the collecting bottle. Students may wonder if this is really happening.

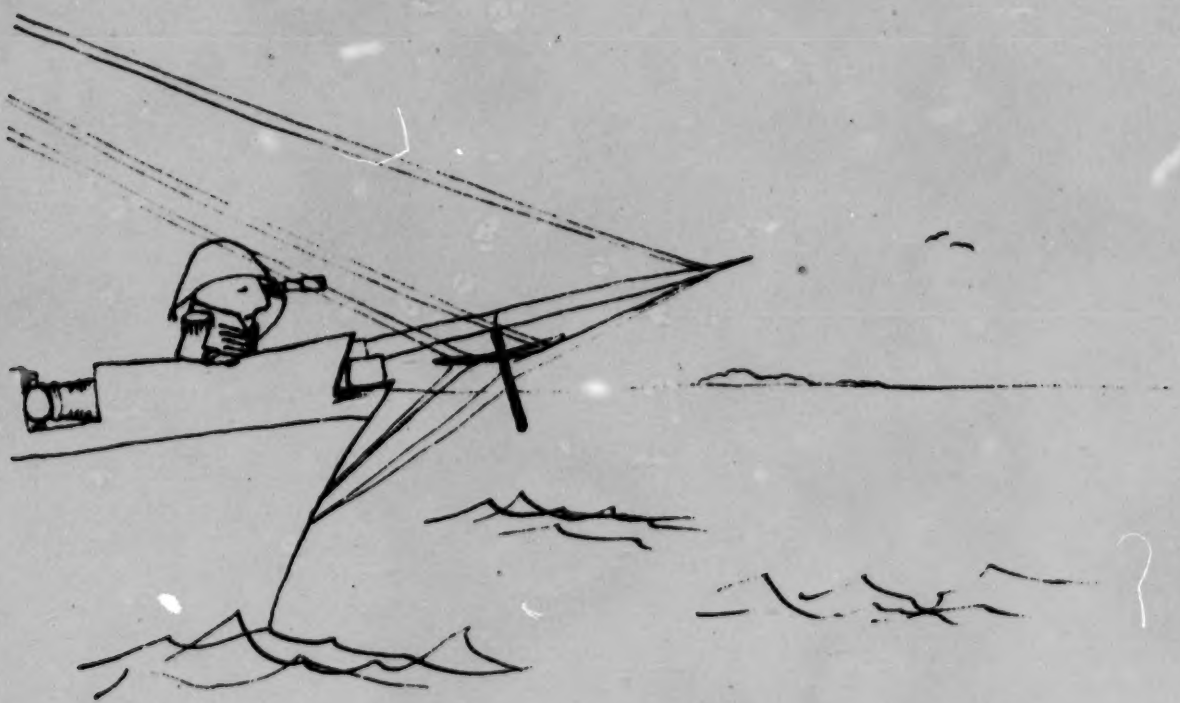
6. Light a match and hold it below the lip of the beaker. If CO_2 is flowing out, the match will go out because of the lack of oxygen.

7. To tell when the collecting bottle is filled with CO_2, lower a match into the bottle to see whether it will go out.

8. As soon as you have finished collecting the CO_2, suspend a thermometer in the bottle and seal the bottle with its cap.

CHAPTER II

OCEANS



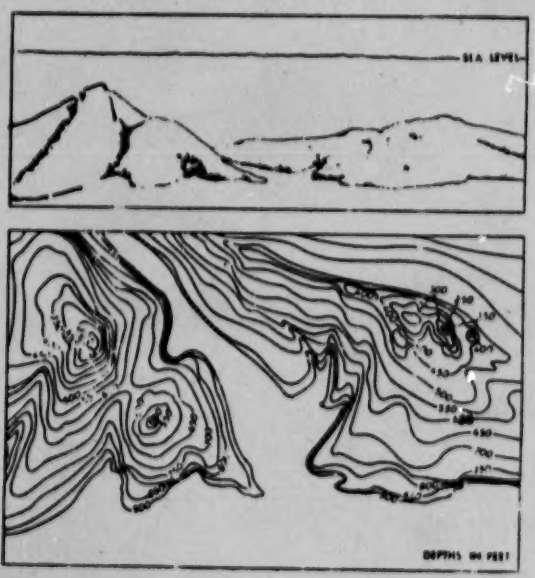
Bathymetric Analysis

Adapted from an activity in the
Naval Study Kit,
U.S. Oceanographic Office,
Washington, D.C., 1968

by
Robert A. Champlin

Introduction

Bathymetric data or ocean soundings tell us something of the changes in depth and configuration of the ocean bottom. Studying the sounding notations on navagational charts aids us in visualizing the outline or slope of the bottom features. By connecting all points having the same depth by contour lines, and by drawing these contour lines at different depth intervals, the bottom can be pictured in graphic form. Contour lines show the shape of underwater ridges, mountains, and valleys, as well as their depth. Successive contour lines that are far apart on the map indicate a gentle slope, lines that are close together indicate a steep slope, and lines that run together indicate a cliff. The manner in which contour lines express depth, form, and gradient is shown in the figure below:



The sketch represents a submarine valley that lies between two hills. In the foreground is a submarine plain. The hill on the right is well rounded and has a ridge extending northwest.

The hill on the left slopes steeply and has two peaks. On the map, each of these features is represented directly beneath its position in the sketch by contour lines.

The contour lines are labeled as shown, and somewhere on the chart it should be stated whether the units are feet, fathoms, or meters.

The variation in depth shown by the sounding notations indicates the type of bathymetric feature under study. A wide sprinkling of shallow soundings ranging in depth could indicate an island shelf. The close spacing of soundings having great variation in depth usually means hilly or rough topography. If the arrangement of these soundings is along a line, it may indicate a ridge. A few soundings circled by other soundings of ever-increasing depths could indicate a conelike feature. If the cone has a narrow summit and has more than 500 fathoms of relief, it is probably a seamount. If the summit is broad and flat, it could be a tablemount. Soundings deeper than the average of the ocean floor may suggest a depression in the ocean bottom. Several of these features will be found on the bathymetric chart in this exercise.

Objectives

As a result of completing this exercise you should be able to:

1. Draw a reasonably accurate contour map of a portion of the ocean floor.

2. Interpret landform features on the ocean floor from the map you draw.

Materials

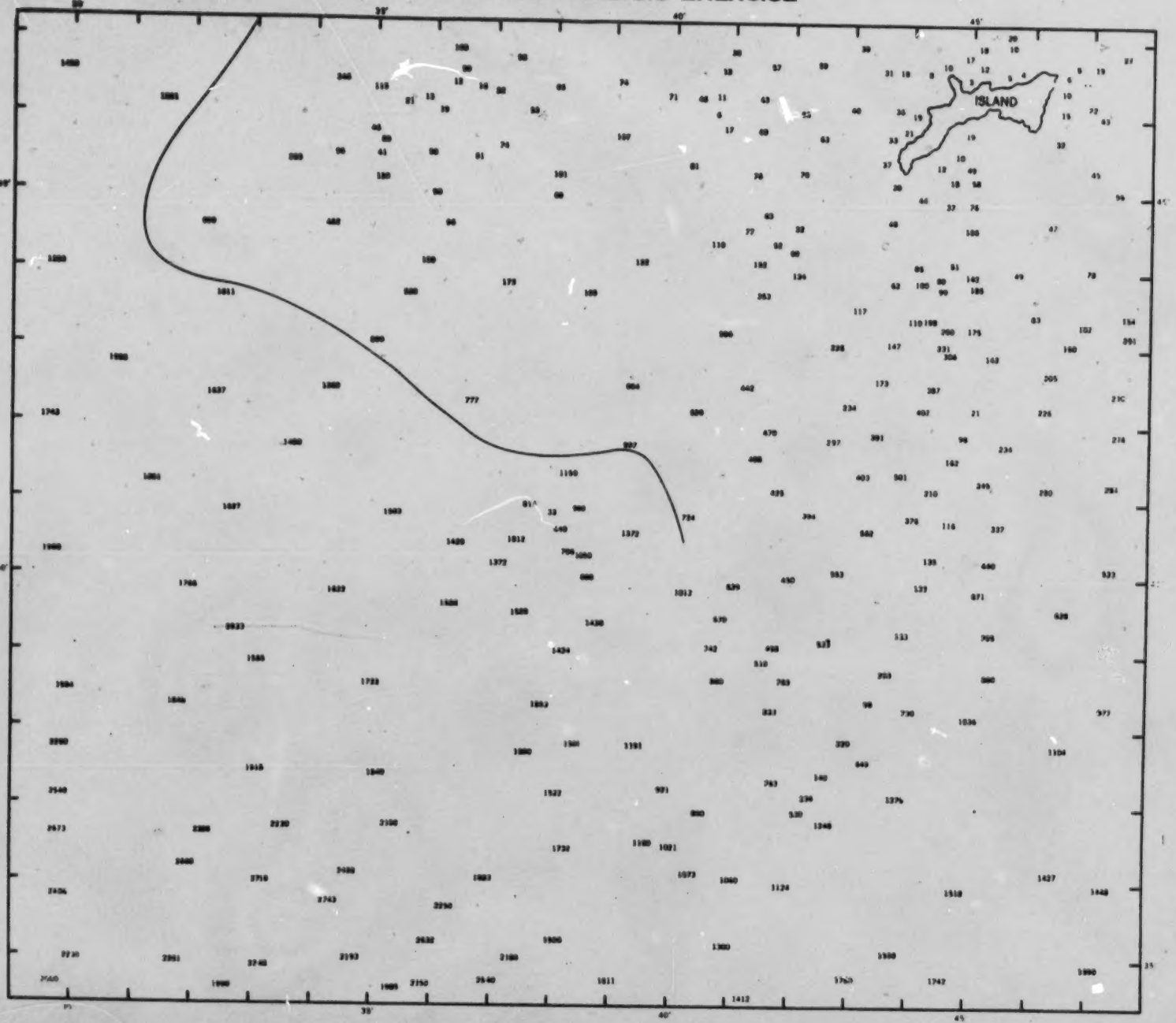
A pencil
A chart entitled BATHYMETRIC ANALYSIS EXERCISE

Procedures

The enclosed chart was taken from a typical navigational chart with sounding notations. Draw appropriate contour lines to show the bottom topography pattern.

The selection of a proper contour interval for this exercise is the first step. Choose a contour interval that will show the bottom features in accordance with the amount of available data. The details of an area with numerous soundings and low relief may

BATHYMETRIC ANALYSIS EXERCISE



be shown by choosing a small contour interval. If detail cannot be shown, as in areas of great relief and scattered soundings, a large contour interval may be desirable. A combination may be useful; that is, a small contour interval in shallow waters and a larger interval in progressively deeper water (see suggested contour interval below). Too many contours can be confusing; too few may be misleading.

Suggested	contours (in fathoms)
10	400
20	500
50	1000
100	1500
200	2000
300	2500

A contour is a line connecting all points at the same elevation and closing upon itself. The contours of the smaller features will close within the area of the chart. The contours of the larger features may not close in the chart area, so do not worry about their closure.

Contouring is based on the assumption that there is a constant slope between points on a surface. This is not always true but is useful for our purposes. The shape of the contour is controlled by the sounding notations. The drawing of the contour can be done fairly accurately by approximation (the most common method of geologists).

The approximation method requires the plotter to be skilled in recognizing and imagining the bottom shape from the sounding notations. While imagining the type of features described by the sounding, dash in a line on a trial basis representing the path of certain essential contours, such as those at 100, 1,000, and 2,000 fathoms.

Once enough control points or dashes have been drawn to outline features, sketch in a smooth flowing line connecting the points or dashes. On the Bathymetric Analysis Exercise a portion of the 1,000-fathom contour has been drawn to assist you in getting started. Try to keep your lines free from wiggles or right-angle turns. Number each contour as it is drawn to avoid joining contours of different depths. As you draw, various features will become visible, such as a seamount, depression, trough, ridge, island shelf and slope, submarine canyon, and reefs.

Ocean Currents

Adapted from an activity developed by
Project COAST, Delaware Sea Grant, 1974

by
Victor J. Mayer

Introduction

The existence of ocean currents has been known for many years. Benjamin Franklin was the first American to study an ocean current. He wondered why the mail ships took two weeks longer than merchant ships to make the trip from England to America. His cousin, a whaling captain, said that the merchant captains knew of a place in the ocean where the water flowed like a river.

Sailors have known about ocean currents for many years. They have steered their ships so that they could either use currents or avoid them. These currents are surface currents, caused by the wind and rotation of the earth.

The ocean currents affect the climate of the land masses nearby. Their circulation patterns distribute oxygen in the ocean waters. Ocean currents are still used by man in his travels on the water. The currents may also influence the fishing in an area when the upwelling carries nutrients to the surface. Partly because of their importance to ocean travel and fishing, currents in the Atlantic Ocean have been studied more extensively than those of other oceans.

Little is known about the ocean currents that flow beneath the surface of the ocean. They are difficult to study because they are not so easily observed as surface currents. As recently as 1951, a new current, the Cromwell Current, was discovered in the Pacific Ocean. This current flows from west to east along the equator, but its presence is masked by an overlying surface current flowing in the opposite direction.

Deep currents are caused mainly by differences in the density of adjacent water masses.

Objectives

At the conclusion of this activity the student will be able to:

1. Explain why ocean currents are important to man.

2. Demonstrate the effect of a temperature increase on water density.

3. Demonstrate the effect of a salinity increase on water density.

4. Demonstrate that differences in water density create currents.

Part A

Background

It was once believed that the deeper parts of the ocean were without life. This idea has been disproved recently by photographs that oceanographers have taken of animals living in these deep parts of the ocean. This indicates that there must be some way that the oxygen-rich water necessary for life reaches these depths. The deep ocean currents may be responsible.

Florida and Baja, California, are at the same latitude, and the average air temperature for both places is about the same. The temperatures of the water off the coast of both locations are extremely different. Florida waters, warmed by the currents from the equator, may reach temperatures of 30°C while the waters off Baja, California, are cooled to near 15°C by currents coming down from the North Pole.

Research indicates that the burning of fossil fuels should be increasing the carbon dioxide content of the atmosphere about 0.5% per year. The actual increase is only about 0.2%. It is presumed that the remainder of the gas is dissolved in the waters of the oceans. The currents of the oceans determine, to a large extent, how much gas can be stored in the ocean water since their movement is constantly agitating the surface. Wind-driven waves also play an important role in this carbon dixoide absorption. The waves increase the surface area and allow the water to perform more efficiently in absorbing carbon dioxide.

The density of sea water is determined by two factors: salinity and temperature. Salinity is the amount of dissolved salts in the water. As the salinity of sea water increases, its density increases in direct proportion. As a volume of sea water is heated, its density decreases; as it is cooled, the density increases. We say that the density of sea water is directly proportional to its salinity and inversely proportional to its temperature.

In areas where the evaporation rate is greater than the rate of precipitation, the salinity of sea water increases as does its density. This dense water moves downward and is replaced by

water from below which is less dense. This increase in salinity (and density) is due to the fact that only the water evaporates and the salts that were dissolved in it are left behind.

Around Antarctica is the densest ocean water in the world. Freezing affects both the water and the dissolved salts in it. You may recall that a decrease in temperature causes an accompanying increase in density. As the water freezes, its salinity increases. This increased salinity increases the density of the already dense cold water. This extremely dense water sinks to the bottom where the water is less dense and flows beneath it. This is called the Antarctic Bottom Current. (See the diagram on p. 38.)

The Gulf Stream carries warm, salty water into the colder North Atlantic around Greenland. There it cools and increases in density. Some of it then sinks toward the ocean bottom, creating undersea currents as it goes. This is called the North Atlantic Deep Current.

Procedure

(See page 39 for answers to following questions.)

1. In the diagram on page 38, which current is initiated by an increasing density due to temperature change?

2. Which current is caused by an increasing density due to a salinity increase?

3. Why does the Antarctic Bottom Current flow under the North Atlantic Deep Current?

4. Where is the densest ocean water in the world? Why is the water in this area so dense?

5. Why do we know more about surface ocean currents than we do about deep ocean currents?

6. What is the main cause of deep ocean currents?

7. Why are the ocean currents important to man?

8. What is salinity?

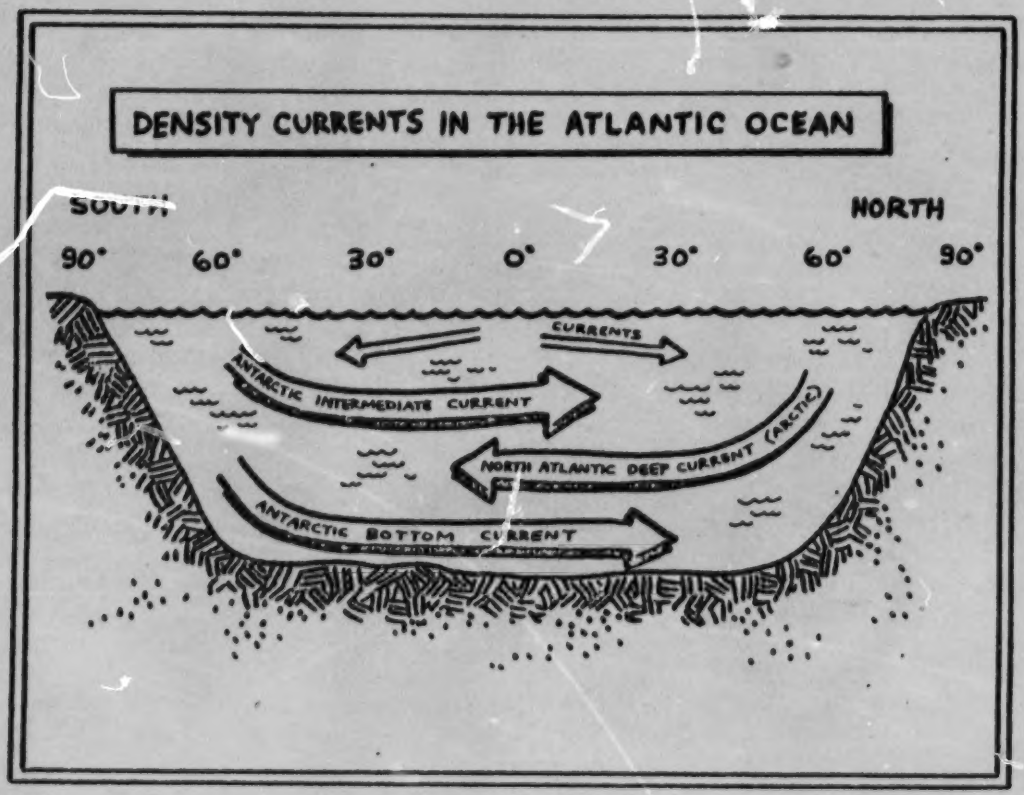
9. What factors affect the salinity of the water?

10. Why do you think we know more about the Atlantic currents than we do about the Pacific currents?

11. How does an increase in the salinity of sea water affect its density?

12. How does an increase in the temperature of sea water affect its density?

13. Do you think all of the currents in the ocean have been discovered? Why or why not?



Answers

1. North Atlantic Deep Current

2. Antarctic Bottom Current

3. Because it's denser

4. The densest ocean water in the world is found in the Antarctic because it is the coldest and saltiest water.

5. Surface currents are more easily observed than deep currents.

6. The main cause of deep ocean currents is differing densities of adjacent masses of sea water.

7. Ocean currents affect transportation, climate, and fishing.

8. Salinity is saltiness or a measure of the amount of salts dissolved in the water.

9. Evaporation, precipitation, and freezing affect salinity.

10. The Atlantic Ocean is more heavily travelled and smaller, therefore it is more easily studied.

11. An increase in the salinity of a body of water will cause an increase in its density if the temperature remains constant.

12. An increase in the temperature of a body of water will decrease its density.

13. No. A large portion of the oceans has not been explored to any great extent.

Part B

1. Show that Heat Makes Water Lighter

   Materials: drinking glass, pill bottle, ink or dye, eyedropper

   Procedure: Fill the glass nearly full with COLD water, then fill the pill bottle 2/3 full with COLD water. Using the eyedropper, add ten drops of ink to the pill bottle. Carefully place the pill bottle, right side up, in the glass. Because the water in both the glass and bottle are cold, nothing will happen.

   Now empty the pill bottle and refill it (2/3 full) with HOT water. Put ten drops of ink in it and as was done above, place it, right side up, in the glass. When the inky water cools, it will become heavy again and will sink to the bottom of the glass.

2. Increase the Density of Water.

   Materials: drinking glass, fresh egg, salt, tablespoon

   Procedure: Place the egg in a drinking glass that has been nearly filled with tap water. The egg will sink because it is more dense than the water.

   Now remove the egg from the glass. Add two heaping tablespoons of salt and stir until the salt is dissolved. Put the egg into the water again. This time the egg will float because the salt has increased the density of the water so that the water is now more dense than the egg.

3. Demonstrate That Density Differences Create Currents

   Materials: drinking glass, ink or dye, eyedropper

   Procedure: Fill the glass almost full with WARM water and let it stand until it is still. Now carefully add one or two drops of ink to the surface. The ink stays in one spot for only a short time. It begins to move downward, making beautiful patterns as it goes. The ink is denser than the water and will replace the water below. This is how the currents in the Antarctic got started.

4. Demonstrate that Density Differences Create Currents in a Model Ocean.

Materials: large rectangular baking dish, four aquarium thermometers, paper cup with several small pin holes in the bottom, masking tape, crushed ice (enough to fill the paper cup), vegetable dye, bits of paper

Procedure: Tape the paper cup in one corner of the baking dish so that there is about one-half inch between the bottom of the dish and the cup. Place the thermometers at regular intervals along the bottom of the baking dish. Be sure the bulbs are facing the same direction. Tape the thermometers in place. Add enough water so that the bottom of the paper cup is covered. Let the apparatus sit until there is no movement in the water.

Read each thermometer and record the temperature. This is important because we are concerned with how much the temperature changes. Fill the cup with ice and add 5-10 ml of vegetable dye. Record the thermometer reading at five minute intervals for half an hour. Place a bit of paper on the water in the corner opposite the ice. In what direction does it move?

If you cannot see a bottom current, gently heat the dish opposite the ice to increase the current and make it easier to follow. What happens to the bottom current when it reaches the other side of the dish? Why? Which was the last thermometer to show a temperature drop? (The dye should show the existence of a bottom current; the paper should show the direction of a surface current.)

Density Currents

Adapted from an activity in the Preliminary
Edition of Investigating the Earth,
Earth Science Curriculum Project,
Boulder, Colorado, 1964

by
Robert A. Champlin

Introduction

The way in which water circulates or mixes throughout the ocean has long been of interest to scientists. One of the reasons that ocean water is able to circulate vertically is due to differences in density.

The density of sea water varies because of differences in temperature and salinity (salt content). In this activity you will investigate just how water of different temperature and salinity characteristics behaves.

Objectives

When you have completed this activity you should be able to:

1. Make accurate statements about how density varies when salinity is altered, when temperature is altered, and when both salinity and temperature are altered.

2. Make reasonably accurate predictions about the behavior of two different "bodies" of water which differ in salinity and temperature when these two characteristics are known.

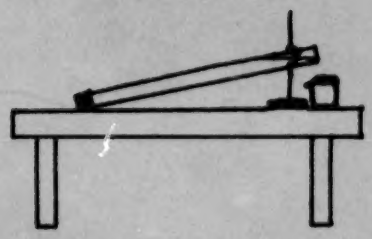
Materials

Ring stands
Clamps
Clear plastic tubes (approx 32" long)
Rubber stoppers
Fish tanks or clear plastic shoe boxes
Salt
Water
Food coloring
Ice cubes
Test tubes
Plastic baggies
Small buckets or beakers

Procedure

Part 1

Set up the long plastic tubes up as shown in the diagram below.



A. Pour water with a salinity of 35 parts per thousand into the plastic tube. (Your teacher will tell you how to do this).

B. Make another saltwater solution of 37 parts per thousand (°/oo) with water of the same temperature as in the plastic tube.

C. Mix some food coloring with the 37 °/oo water. Don't make it too dark!

D. Pour a test tube full of colored water into the plastic tube and observe what happens. Write down your observations.

E. Repeat steps A - D but this time use warm (20°C) water in the plastic tube and pour in a test tube of cold water (10°C). Again write down your observations.

F. Repeat steps A - D a third time but this time put water with a temperature of 20°C and a salinity of 37 °/oo into the plastic tube. This represents sea water from low latitudes. Pour in colored water with a temperature of 10°C and 35 °/oo salinity. This represents high latitude sea water. Again note what happens.

Your teacher may suggest other combinations.

After you have done steps A - F answer these questions.

1. What is the effect of salinity on the density of water? What is your evidence?

2. What is the effect of temperature on the density of water? What is your evidence.

3. Can you think of another way to further test your ideas about these effects?

The Types of Tide and The Tide Curve

Adapted from an activity in the
Naval Study Kit,
U.S. Oceanographic Office,
Washington, D.C., 1968

by
Robert A. Champlin

Introduction

Nearly everyone has heard about the daily rise and fall of the tide. Tides are caused by gravitational forces of the sun and moon. Information about the tides has always been of great importance to navigation, especially in guiding ships in and out of a particular area. It is essential before an amphibious operation can be planned where boats, men, and materials have to be landed along some distant shore. Another way in which tidal information is used is in designing generating plants for electricity by the use of tidal energy.

In order to study the tides, we must take observations of the time and amount of rise and fall of the tide each day over a long period. These observations are usually taken automatically by an instrument that rises and falls with the tide and makes a recording, such as the typical tide curve shown on the next page. After a number of recordings are collected for various places around the world, certain characteristics of the tide can be discovered and predictions made for the future.

There are three classifications of tides.

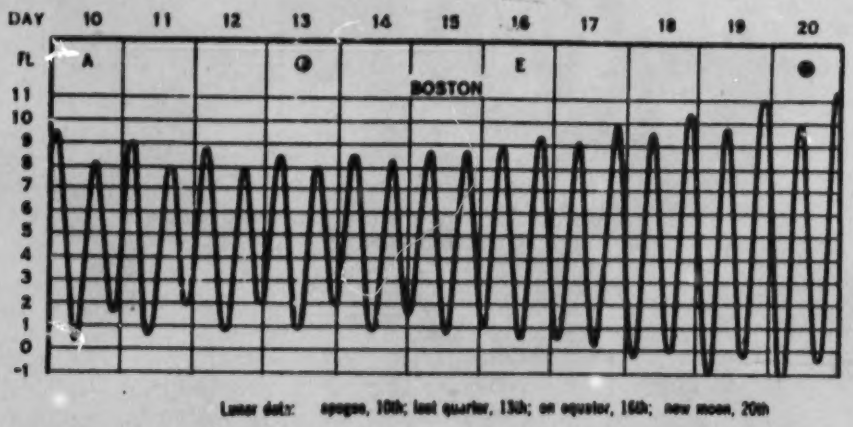
(1) SEMIDIURNAL, which has two high waters and two low waters each day with little or no difference between consecutive high or low water heights. Tides along the east coast of the United States, for example, are of the semidiurnal type.

(2) DIURNAL, which has only one high water and one low water each day. The tides along the Vietnam-China coast are diurnal.

(3) MIXED, which has both diurnal and semidiurnal characteristics. That is, there are two high waters and two low waters each day but with considerable difference between heights of successive high waters or successive low waters; these differences are called DIURNAL (daily) INEQUALITIES. The tides along the Pacific coast of the United States are mixed.

When the moon and sun are in a straight line with the earth (new or full moon every two weeks), they pull together and the tides are greatest. These are SPRING TIDES that occur when the water springs up (the term spring has nothing to do with the season of the year).

When the moon, sun, and earth form a right angle (first and last quarters), the pulls oppose each other and the water is nipped or lowered; these are NEAP TIDES. The accompanying figure shows a typical tide curve related to the phases of the moon for an 11-day period; the changes in the moon's position with respect to the sun and earth are called phases.



Lunar data: apogee, 10th; last quarter, 13th; on equator, 16th; new moon, 20th

A graphical representation of the rise and fall of the tide can be shown by plotting a curve from predictions of times in hours and minutes, and heights in feet, for specific days. Predictions of tides occuring in future are made mathematically from past tide observations and from knowledge of the motions of the earth, moon and sun in space.

Objectives

As a result of completing this exercise you should be able to:

1. Plot a tidal flucuation graph.

2. Interpret a tidal flucuation graph.

Materials

Tide prediction chart
Tide curve graph

52

Procedure

Plot a tide curve from the tide predictions given below. The first day has been plotted on the accompanying graph. Complete the tide curves for day 2, 3, and 4 by plotting the times and heights and connecting all points; then try to answer the questions.

DAYS	TIDE PREDICTIONS		
	TIME*		HEIGHTS*
	Hours	Minutes	Feet
1	01	15	1.0
	07	30	4.1
	16	00	1.0
	20	15	4.0
2	02	00	1.0
	08	30	6.5
	14	15	2.0
	21	00	5.0
3	04	15	0.0
	16	00	7.0
4	04	30	1.0
	10	00	3.0
	16	00	1.0
	22	00	2.9

*The days are divided into 24 hours (0 to 24), midnight to midnight. Heights are measured from the zero reference line.

QUESTIONS

1) During what day is the tide diurnal?

_____

2) During what day is the tide mixed?

_____

3) During what days is the tide semidiurnal?

_____, _____

4) During what day is the range largest?

_____

5) What is the smallest range and on what day?

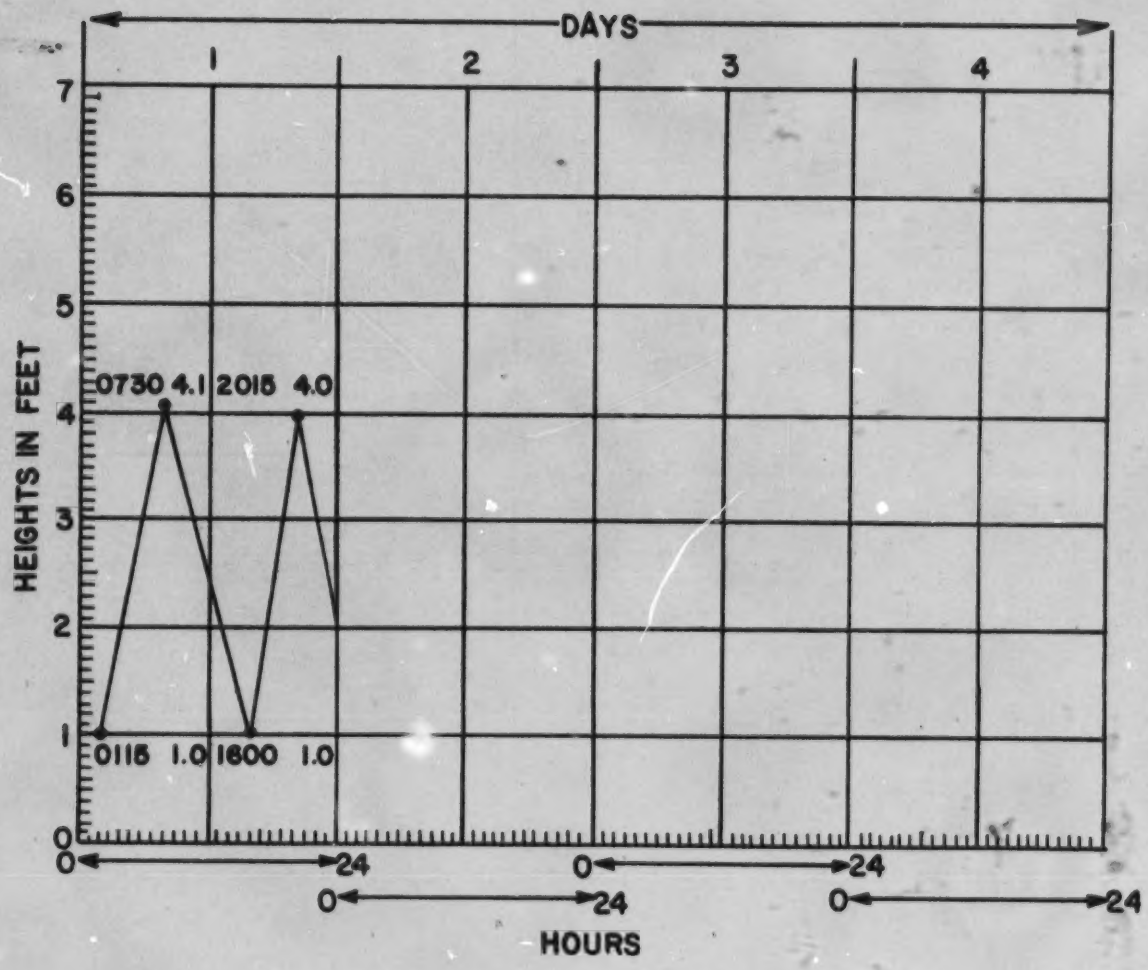
_____ft. _____day

6) What is the largest diurnal inequality shown?

_____ft. On what days?

_____ _____

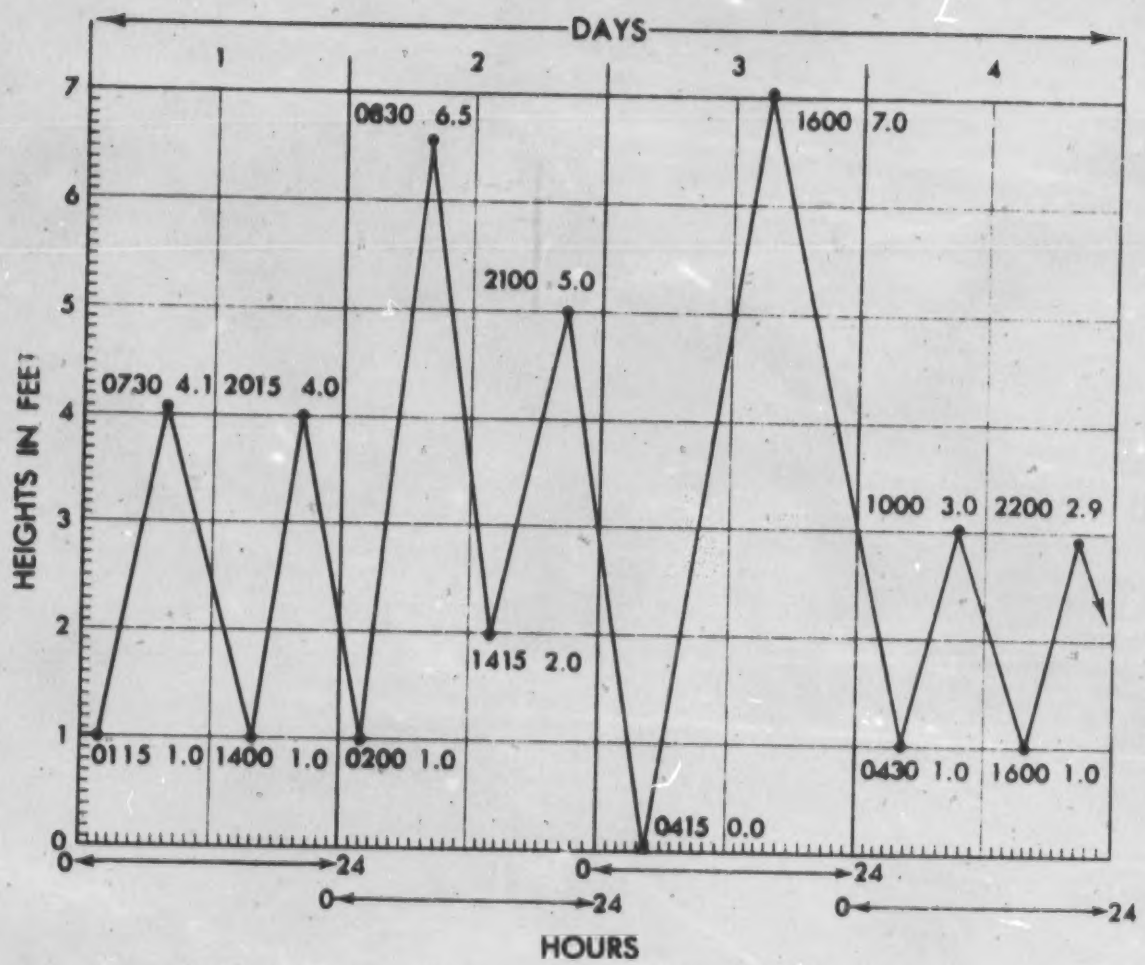
EXERCISE 1


DAYS
1
2
3
4
HEIGHTS IN FEET
0
1
2
3
4
5
6
7
0730 4.1
2015 4.0
0115 1.0
1600 1.0
0
24
0
24
0
24
0
24
HOURS

EXERCISE 1

DRAWING A TIDE CURVE

SOLUTION



1) The tide is diurnal on Day 3.

2) The tide is mixed on Day 2.

3) The tide is semidiurnal on Day 1 and Day 4.

4) The range is largest on Day 3.

5) The smallest range is 1.9 feet on Day 4.

6) The largest diurnal inequality is 4.0 feet on Days 3 and 4.

Coastal Processes and Erosion

An activity developed by
Oceanic Education Activities for
Great Lakes Schools,
a project of Ohio Sea Grant, 1980

by
Beth A. Kennedy
and Rosanne W. Fortner

Introduction

The major natural forces affecting the shoreline are wind, waves, and currents. These forces wear away and build up a shoreline. People can modify these forces and redirect them, but we will never totally control them.

Wind and Waves. Waves have significant effects on shorelines. During storms, their energy can carry beach sands lakeward, erode cliffs and banks, and damage or carry away man-made structures. During calm periods, waves move offshore sand onto the beaches, building them up.

Currents. Currents--streams of moving water within a body of water-- are another major force affecting the shorelines. Perhaps the most important current causing the shoreline to change is the longshore current, which is generated by waves as they strike the coast at an angle. A longshore current runs parallel to the shoreline and varies in speed and direction with the angle of waves and their energy. It often transports large quantities of sand along the beach. This transportation is known as littoral drift.

If there is an abundant supply of sediment, as from eroding cliffs or sediment-laden streams flowing into the lake, the littoral drift will deposit sediment wherever its speed is reduced. When sediment is scarce, the littoral drift will carry sand away from the beaches, causing erosion.

Because wind and waves determine the directions and amount of littoral drift, the overall or net sand movement in Lake Erie is from west to east.

Objectives

When you have completed this investigation you will be able to:

1. List the major natural forces of erosion along the lake shore.

2. Describe how the rate of erosion differs with different materials.

3. Explain the purposes of the three major categories of shoreline protection devices.

Materials

Three rectangular plastic pans or plastic shoes boxes
One piece of board (2x4 or plank) as long as the width of the pans
Sand
Soil
Several broken pieces of rock
Ruler
3x5 note card cut in three long strips
Pencil for recording data

Procedure

Part A. What Causes The Shoreline To Erode Away?

1. In the end of one of the plastic pans place three handfuls of wet sand.

2. Using a piece of board, mash the sand up against the end of the pan and flatten the top. Make this "beach bluff" about as wide as it is high.

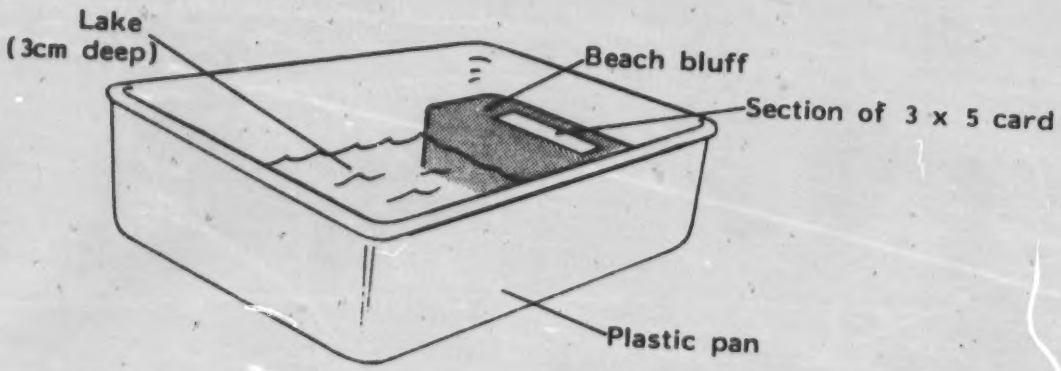


Figure 1. Shoreline Model

3. Repeat steps 1 and 2 with a second pan, building a beach bluff made of wet soil.

4. In one end of the third pan make a stack of rock pieces that will represent a rocky shoreline about the same size as the other bluffs.

You should now have three "beach bluffs" of various types and sizes of material. The three pans represent lakes.

5. Hold the piece of board up against the sand bluff to protect it while you slowly add water to the empty end of the pan. Create a lake about 1-1.5 cm deep. Remove the board gently when the lake water is still.

6. Repeat Step 5 to create lakes in front of the soil and rock bluffs.

7. Gently place a strip of note card flat on top of each bluff.

8. You are now ready to act as the wind, making waves and causing erosion on the shoreline. Using a ruler or the piece of board, make waves that move toward the beach bluff from the opposite end of the lake. Start gently, counting the number of waves you produce. Then gradually increase the strength of your waves as if the wind were becoming stronger. Record what happens to the beach bluffs as you repeat this process in each lake.

9. When the section of note card slips toward the water, your bluff has collapsed. If collapse has not occurred after 60 waves, stop and record your observations of the bluff's condition.

NOTE: To measure the height of the waves, find the distance from the top (crest) of the wave to the lowest part (trough) of the wave. Do not measure from the bottom of the "lake" basin unless the bottom is actually exposed as the wave passes by.

1. Which beach bluff is the least stable (collapsed first)?

2. Which beach bluff is the most stable (withstood the most waves)?

3. Some beach bluffs on Lake Erie's shore are actually made of sand and some of clay similar to the soil bluff you constructed. The rocky bluffs of the lake shore may be of limestone or a soft shale.

   What type of beach bluff would you pick if you were building a cottage on the shoreline? Why?

4. Below is a map of Lake Erie's shoreline. Based on what you have discovered about how different materials erode,

   a. Put X's on the sections of shoreline that are probably made of rock.

   b. Put O's on the sections of shoreline that are probably made of sandy material.

   (You do not have to cover the shoreline with either X's or O's. The shape of the shore may not give you any clues about the type of material it has.)

5. Some points of land sticking out into the lake may be made of sand. What process is probably responsible for carrying the sand and depositing it there? (Re-read the introduction to Part A.)

6. How could you tell from their appearance which points of land might be sandy instead of rocky?

Erosion of coastal areas, as you have seen, occurs at different rates depending upon the material making up the shoreline. The same processes act upon the ocean as upon large lakes. Some of the coast of England, for example, has been worn back more than 3 km since the time of the Romans. The shore of

Cape Cod retreats at the rate of 25 to 150 cm each year. These coasts are composed of relatively weak material, but the same process takes place more slowly in the hardest rock.

Part B. Can Erosion Be Stopped?

The shores of the Great Lakes are subject to the attack of winds, waves, longshore currents, ice, and floating debris. Winds having an average velocity of more than 40 km per hour and lasting from 6 to 10 hours are capable of creating waves from 2 to 3 m high on many portions of the Great Lakes. Some shoreline areas suffer damage from smaller waves as well as from the larger ones.

The possibilities for erosion along ocean shorelines are even greater. For instance, at Minot's Ledge in Massachusetts, waves from severe storms destroyed a lighthouse several times during its construction. In 1951, when the light was finally completed, waves brought the entire structure crumpling into the sea, killing its two keepers and leaving little evidence that the light had ever been there.

About 83 percent of Lake Erie's erodible shoreline is privately owned. Therefore, land owners must protect their shorelines. Methods of erosion prevention involve attempts to keep the force of the waves away from the bluffs. By chance, nature protects shorelines by building sand beaches where the waves can break and use up their energy before reaching the bluffs. People can construct devices which duplicate the effectiveness of natural sand beaches.

Erosion cannot be permanently stopped, but construction of the proper devices can slow erosion down. What are the devices available to the homeowner and to coastal communities in general?

Materials

. Same as Part A, plus a section of 2 x 4 board equal to half the width of the lake pan.

Procedure

1. A description of each of the three major methods of shore protection follows. After reading each description, carefully examine the diagrams on page 50. Label each diagram by letter (A, B, C) according to the method of shore protection which each one shows.

   (A) One method of shore protection involves the use of concrete, wood or steel structures built directly against

and parallel to the shore. These structures are designed to help keep currents and waves from reaching the erodible shoreline. Some of these structures also serve as docking facilities.

(B) A second method of beach protection is the construction of a device perpendicular to the shore and connected to it. This device traps the sand moving with the littoral drift. A beach is formed, which is excellent protection against shore erosion.

(C) The third method of shore protection is an offshore structure. It usually consists of fairly large stones which are piled away from but parallel to the coastline. The wall of stone reduces wave attack on the shoreline much as a natural sand bar would.

2. Now you can test the effectiveness of some of these shoreline protection devices:

   A. Rebuild the sand bluff at one end of the lake.

   B. Put a short section of 2 x 4 firmly up against the bluff to act as a seawall.

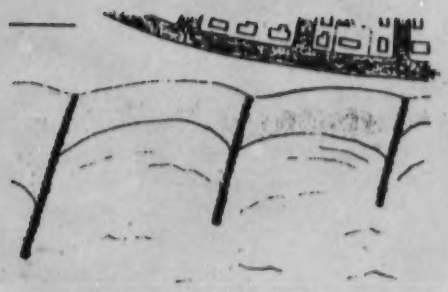
   C. Repeat the wave-making activity as before. Record the condition of the bluff after 5 waves and again after 10 waves.

   D. Repeat step A above. This time place the short 2 x 4 in the center of the basin to form a breakwater about 5 cm from the sandy bluff.

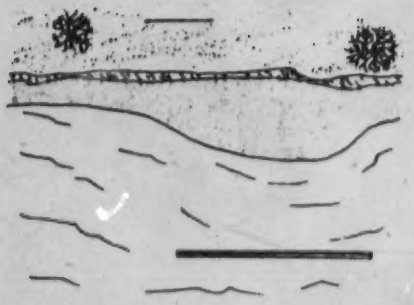
   E. Make some waves again, and record what happens to the bluff after 5 waves and after 10 waves.

3. As you may have observed, the water within your reconstructed sand bluff may have weakened it before wave erosion began. Groundwater and surface streams do the same thing on real lake shores. For this reason, trees, grasses, and shrubs are sometimes planted to go along with some other shore protection device. The life processes of plants remove ground water, the roots hold soil in place, and beach grasses trap sediment to actually help build the beach.

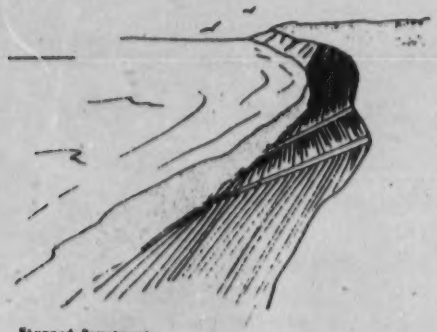
4. In recent years there has been growing concern about the uncontrolled construction of shore protection devices such as groins, seawalls, revetments, and bulkheads. Many people interested in maintaining and improving the environment are concerned about the placement of multiple bulkheads along



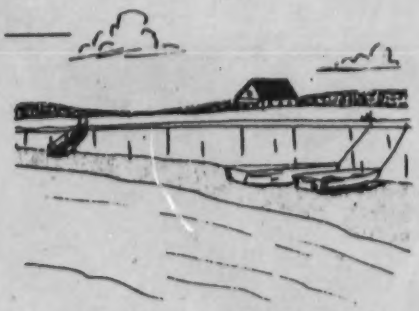
Groins: sheet pile



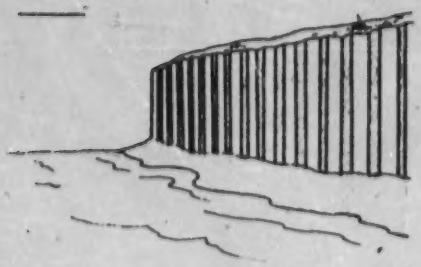
Breakwater: steel pile



Stepped Revetment

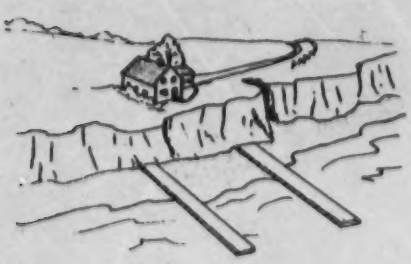


Sea Wall: concrete

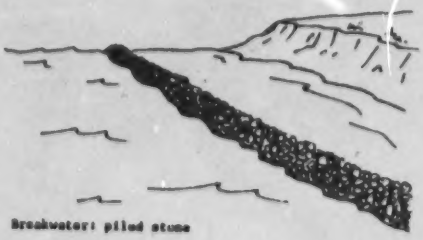


Sea Wall: sheet pile

Sea Wall: cement



Groins: cement



Breakwater: piled stone

stretches of shoreline. Evidence strongly indicates that groins speed up erosion in nearby areas and that bulkheads cause shore loss and water turbidity. Some argue, "What harm does a single 50-foot or 100-foot bulkhead do to the environment?" There are many miles of bulkheads, seawalls, and other protective devices added to our shoreline every year. What is the long-term and the cumulative effect of these structures?

Review Questions

1. List the natural forces which cause erosion along the Lake Erie coastline.

2. What types of shore materials erode faster? Slower?

3. Briefly describe the three major methods or categories of shoreline protection devices.

4. If you had a beach cottage, which type of device would you build to protect your section of shoreline? Explain your choice.

5. Would it be advisable to construct shore protection devices along all sections of Lake Erie's shoreline? Explain.

Microfossils and Ancient Ocean Temperatures

by
Keith M. Schlarb, 1979

Introduction

You may have collected remains of ancient organisms which left their imprint or shell, or bone, in rocks. These remains are called fossils. Fossils can be used to determine the age of rock layers, the kind of organisms that lived and what the environment was like while they lived. During this activity you will be using fossils to determine the temperature of ocean water near Antarctica. The fossils used by scientists for such study are called microfossils because of their small size.

Objectives

At the end of the activity you should be able to:

1. Describe how microfossils can be used to determine water temperature.
2. Explain how the climate of Antarctica has changed.
3. Discuss how microfossils may indicate periods of time when glaciers occurred in Antarctica.

Materials

Samples of microfossils can be obtained from a scientific supply house such as Wards Scientific, Inc. Rochester, New York.

Binocular microscopes.

Part A

Procedure

Examine the samples of microfossils which have been set up under the microscopes.

1. Make a sketch of one of the microfossils. Indicate how much the fossil is magnified.

Single-celled plants and animals live in water that is close to the surface, when they die their shells drift to the bottom.

Microfossils are found in the sediments of the ocean bottom. Certain micro-organisms lived in warmer water while others lived in cool water.

2. Fossil W lived in warm water while Fossil C lived in cool water. You have just collected a sample of sea sediment and upon examination find that 60% of the microfossils are Fossil W and only 10% are Fossil C. Does this sample represent warmer or cooler water?

3. Another sediment sample from a different location has 25% of Fossil W and 75% of Fossil C, does this represent warmer or cooler water?

By using long drills scientists can drill down into the ocean bottom and collect long columns of sediment. The top of Figure 1 is the ocean bottom. The numbers on the left indicate the depth into the sediment. The wavey lines show the percent(%) of warm and cool water fossils found at different depths of sediments in the ocean around Antarctica.

4. From Figure 1 determine the percentages of warm and cool water fossils at various depths and record in TABLE 1.

TABLE 1

Sediment Depth	Sediment Age Million Years Ago	% Warm Fossils	% Cool Fossils	Water Temperature (warm or cool)
0	present	.....	.....	.....
20	1	.....	.....	.....
35	2	.....	.....	.....
60	3	.....	.....	.....
100	4.3	.....	.....	.....
125	6	.....	.....	.....
160	8	.....	.....	.....
180	9	.....	.....	.....

5. Complete TABLE 1 by determining if the percentage of microfossils present represents warm or cool water. Record in TABLE 1.

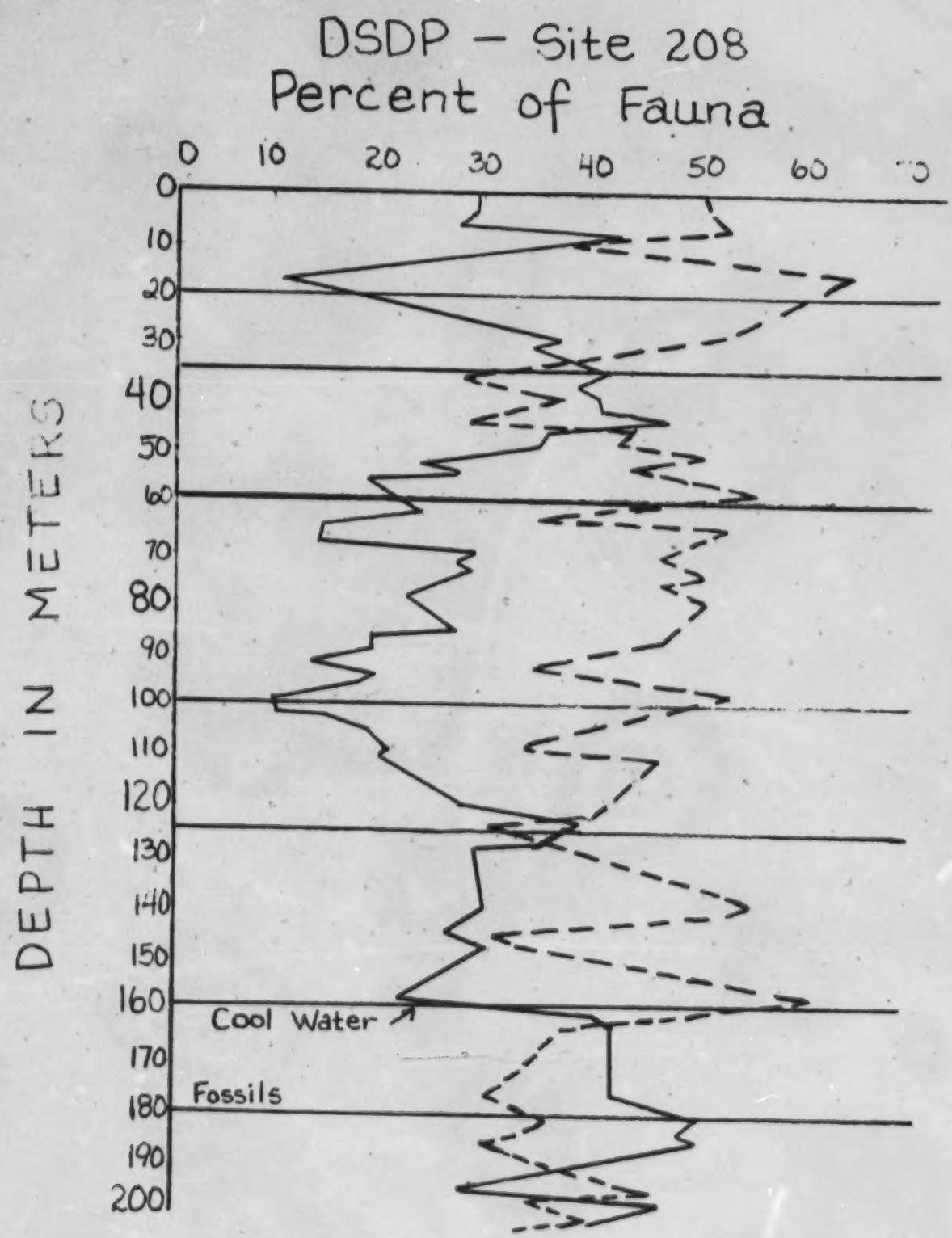

DSDP – Site 208
Percent of Fauna
0 10 20 30 40 50 60
DEPTH IN METERS
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
Cool Water
Fossils

Figure 1

66

6. At the present time water temperature is _____.

7. How often during the past 9 million years has the water temperature been warmer than at present?

8. What information would you use to determine when the warmest temperatures occurred?

9. How many millions of years ago did the warmest temperature occur?

Part B

You have seen how the proportion of different microfossils found in sediment can be used to determine if the water temperature was warmer or cooler in the past. This information, however, is not very significant since we don't know what temperatures represent warm or cool water. Scientists have determined water temperature by comparing the number of two microfossils. Below are illustrations of these two microfossils.

Distephanus

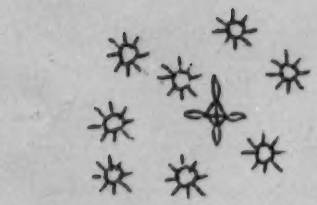
Dictyocha

You are going to determine the ancient water temperature of the Antarctic area much the same as scientists who did the original work.

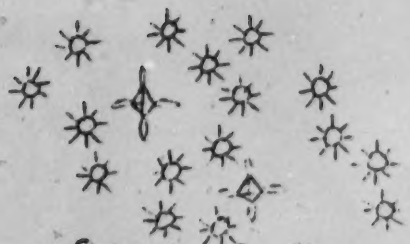
First you must determine the ratio between the two microfossils for each sediment sample. Figure 2 on the next page represents the microfossils found in eight different sediment samples.

1. Count the number of each microfossil for each sediment sample and enter the information in TABLE 2.

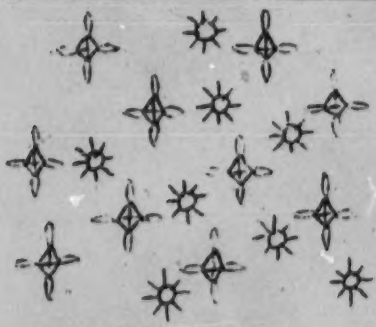
2. Now determine the ratio for each sample. Divide the number in column A by the number in column B.



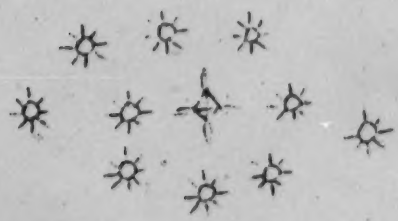
Sample 1 x200



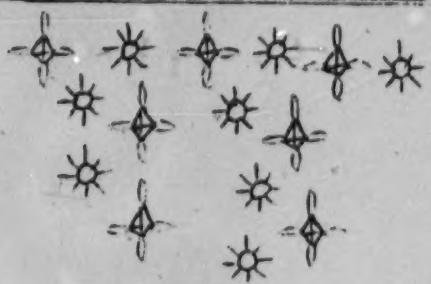
Sample 2 x200



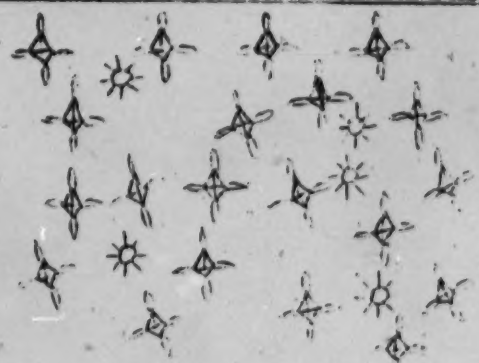
Sample 3 x200



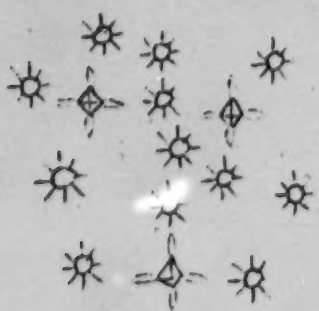
Sample 4 x200



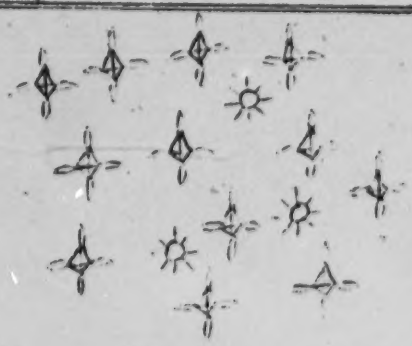
Sample 5 x200



Sample 6 x200



Sample 7 x200



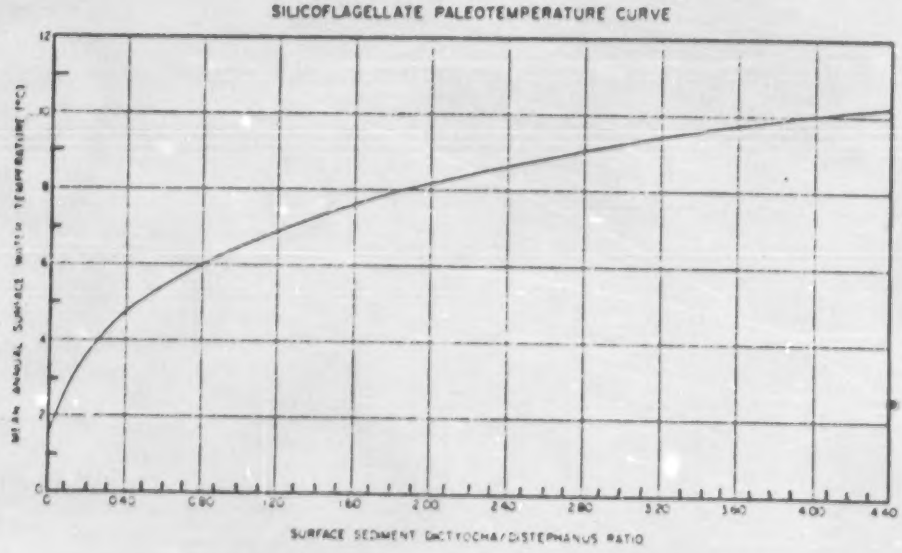
Sample 8 x200

Figure 2

TABLE 2

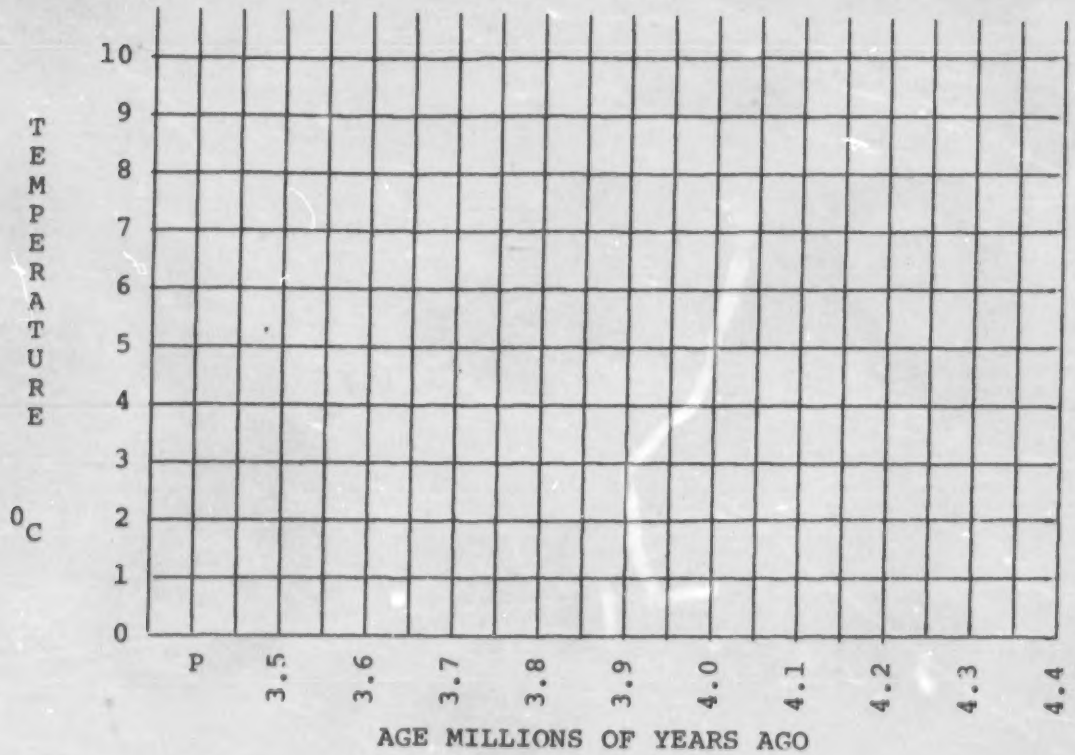
SAMPLE #	A No. of Dictyocha	B No. of Distephanus	Ratio	Temp. °C	age M.Y.A.
1	.....	.....	.....	.....	present
2	.....	.....	.....	.....	3.5
3	.....	.....	.....	.....	3.7
4	.....	.....	.....	.....	3.8
5	.....	.....	.....	.....	3.9
6	.....	.....	.....	.....	4
7	.....	.....	.....	.....	4.2
8	.....	.....	.....	.....	4.25

3. Using the graph below, determine the water temperature from the ratios you've just determined. Record the temperature in TABLE 2.



69

4. Using the temperature and ages from TABLE 2, complete the graph below. Connect the points with straight lines. DO NOT DRAW A BEST FIT LINE.



5. What is the present temperature of Antarctic water?

6. What is the present environment of Antarctic like?

7. What may happen to the size of the glaciers of Antarctica if the climate becomes cooler? If it becomes warmer?

8. Using Graph above, how many millions of years ago would the glaciers of Antarctica have been about the same size as they are now?

9. How many millions of years ago might the glaciers have been slightly smaller than now?

10. During what periods were the glaciers of Antarctica probably very small or non-existent?

11. What might the disappearance of glaciers from Antarctica do to sea level? Explain.

12. What value might knowing the ancient ocean temperatures of Antarctica have for us today?

Summary Questions

1. Explain how microfossils can be used to determine past ocean temperature.

2. What has the temperature of Antarctica been like in the past?

3. How might the microfossils indicate the time period during which glaciers were present in Antarctica?

71

CHAPTER III

THE EARTH AND IT'S SURFACE

Exploring Old Cemeteries

Adapted from the author's activity in
Science Activities, Vol. 3, No. 4,
May, 1970, pp.40-41

by
Thomas J. Rillo

Introduction

Historical events seem to come alive when viewed first-hand on the face of a sandstone, limestone, or granite tombstone. Heightened vitality can result when teacher and class take to the field to explore an old cemetery.

Objectives

After you have completed these activities, you should be able to:

1. Observe tombstones and identify trends.
2. Prepare a tombstone rubbing.
3. Infer relationships among tombstones in a cemetery.
4. Identify the rock material making up various tombstones.
5. Observe differences in weathering related to climate and rock type.

Procedure

Obtain permission before taking your class on a cemetery visit. When visiting a cemetery precautions must be taken so that tombstones and grave sites are not disturbed and that respect is shown at all times.

Tombstone rubbings can be obtained by using crayons, masking tape, a brush, and heavy paper. Select a tombstone that you wish to use for the rubbing. Carefully clean off the stone with the brush and tape the paper on the tombstone. Carefully rub the crayon over the paper to reproduce the inscription or epitaph on the paper. When finished carefully remove the tape and paper. Make sure that the area around the grave is cleaned up before leaving.

1. Find the oldest tombstone and the youngest. Answer each of the following questions for both. What material is it made of? Where is it located in the cemetery? How old was the individual who died? Is there a footstone? How far is the footstone from the headstone? What kind of vegetation is growing on or near the grave? Are there any trees growing adjacent to or on the grave? How old are the trees?

2. When was the graveyard abandoned? How old is the biggest tree growing adjacent to a tombstone or on the grave? What is the date of the latest burial plot?

3. What is the condition of the soil? On the oldest grave? On the youngest grave?

4. Measure the depth of the inscriptions on the oldest tombstone. On the youngest tombstone.

5. Is there evidence of a predominance of a single family?

6. What is the average age of death in ten-year intervals? For men? For women? For children?

7. Do the designs and shapes of the tombstones change through the years? If so, how?

8. Are there any graves that do not have tombstones? How can you tell it is a grave?

9. Can the tombstone and its general appearance relate what the standard of living was for the particular family or era?

10. Did the women live longer than the men? Was this true for one particular era?

11. Is there evidence of an epidemic? What kind of evidence?

12. Are there any unusual epitaphs on the tombstones? If so, why are they unusual?

13. What types of rock have been used for tombstones?

14. Do tombstones made with certain rocks withstand weathering better than those made with another rock? How can you tell?

15. Does one side of a tombstone weather more than another? What could cause this?

Rocks from Layered Sediments

by
James A. Coe, 1975

Objectives

When you have completed this activity you will be able to:

1. Describe similarities between certain sediments and certain rocks.

2. Explain two processes that change sediments to rocks.

Materials

Clay, sand, and pebbles
Shale, sandstone, and conglomerate
Petroleum jelly
A piece of plastic tube ten cm long and two cm wide
A round wood dowel ten cm long that fits in the tube
A square wood base to stand the tube on
A hand lens
A wooden mallet
Plaster of Paris
100 mL beaker
Plastic wrap

Procedures

1. Examine the rocks and the sediments with the hand lens. What similarities do you see between the sediments and the rocks?

2. Rub a thin layer of the petroleum jelly around the inside of the tube. Stand the tube on the wood base and fill the tube to a height of about four cm with sand. Place the wood dowel in the tube and holding the tube firmly on the wood base, use the mallet to compress the sand. When you feel the sand is compressed as much as it can be, lift the tube gently and push the sand core onto a sheet of paper.

3. Using the hand lens examine the sand core. Does it look like the sandstone? This is one way sandstone is formed. This is called compaction and in nature is due to the weight of the other materials on top. Now let us find out what happens if we put sand and clay together.

4. Dampen the sand with a small amount of water and mix it with the clay. Stand the tube on the wood base and fill it with the mixture of sand and clay. Insert the wood dowel and tap it with the mallet. When you think it is compressed enough push the core out on a piece of paper as in Step 2.

5. Using the hand lens, examine the core and describe it.

6. Smear the inside of the tube with some petroleum jelly and stand it up on the wood base. Mix two teaspoons dry sand and one teaspoon plaster of Paris in the beaker. Adding a few drops of water at a time, stir the mixture until it is dough-like. Quickly put mixture into the tube and insert the dowel. Tap the mixture gently and let it stand about five minutes. When the five minutes are up, gently push the core out onto the plastic wrap. Let it dry for about fifteen minutes and then examine it. Describe what you see. This is called cementation. The plaster of Paris acts as a cement to stick grains together.

7. What is the name of the rock you have made?

8. Repeat the experiment you did in Step 6, except this time instead of two teaspoons of sand use one teaspoon of sand, 1/4 teaspoon of clay, and 3/4 teaspoon of pebbles. Do everything else as you did before. Examine this "rock" specimen and describe it.

9. What is the name of the rock you have made?

10. What are the two processes that change sediments to rocks?

Panning for Gold

by
James A. Coe, 1975

Objectives

When you have completed this activity you will be able to:

1. Explain how materials differ in density.

2. Describe how the different densities of minerals can be used to concentrate a particular mineral.

3. Determine the source of a mineral found in a placer deposit.

Materials

An aluminum pie plate or shallow dish

A mixture consisting of sand and gravel with some iron pyrite (fool's gold)

Procedure

Part A

In this activity you are going to try to recover fool's gold by using the methods used by the prospectors during the California gold rush. This technique is called panning.

1. Place the sand and gravel mixture in the pie plate and fill it with water.

2. Gently agitate the contents of the pan by slowly swirling it with both hands.

3. When and if the water becomes cloudy, gently and carefully tip the pan and allow the water to run off.

4. Pick out any large stones.

5. Fill the pan with water again and swirl it as you did above, except now tilt it forward slightly so that the water and sand slowly flow over the edge. Continue to do this until most of the sand has been removed. Give the pan a quick swirl so that the material remaining in the pan is spread out on the bottom of the pan.

6. Pick out any of the gold specks you see. Keep doing this until you think you have removed all the gold.

7. Why was the fool's gold left behind in the pan and not washed out with the sand and gravel?

Part B

Many metallic minerals (minerals which contain valuable metals such as gold, silver, and lead) are heavier than sand, gravel, and clays as you found out in Part A. Where do these minerals come from? See if you can figure it out from this stream problem.

The diagram represents a stream system. A prospector found some valuable metallic minerals at point A on the main stream. Such a deposit is called a placer deposit. He decided he would try to find out where they came from. He started moving upstream panning at various spots to see what was there. He panned at point B but found no valuable minerals. At point C he again found nothing. At point D he found the valuable minerals again. At E and F he found the minerals but did not find them at G or H.

1. From which point were the minerals coming?

2. How do they get into the stream?

3. How did they get to point A?

78

Classifying Fudge and Rocks

This activity has been adapted from the author's article which appeared in Teacher, March, 1980, v. 97, p 68-69.

by
Maurice L. Schwartz

In this activity you will begin by making some candy. Can you guess how making candy can be related to geology? If you cannot, you will have to do the exercise to find out. We do not want to give the answer away and spoil your fun of making candy.

Objectives

Upon completion of this activity you should be able to:

1. Describe how the different kinds of candy were made.
2. Tell why the candy was different.
3. Explain how the ideas learned from making candy may be used to understand some rocks.

Materials

Four teams are needed for this activity. Eight or twelve teams might be formed if enough equipment is available so that all the items listed below can be doubled or tripled. As a minimum, four teams will need the following:

4 Electric hot-plates
4 Small sauce pans or cooking glassware, 4 cup or 600 mL in size
4 Measuring cups
4 Stirring rods
4 Hot-pads or gloves
2 Aluminum pie tins
2 Basins half filled with crushed ice or ice cubes (The basin must be large enough to hold one pie tin.)
4 Teaspoons
2 Lbs. of granulated sugar
Vanilla extract (small bottle)
Powered cocoa (small box)
Table salt (small amount)
4 set of rocks prepared by your teacher

Each set of rocks should contain four specimens. These are gabbro, basalt, granite and rhyolite (or felsite).

You may have to borrow these from the science department of a near-by high school.

Procedure

Part A

This activity begins by making some simple candy. Each team will make one batch. Follow this procedure:

Step 1 Measure 1/2 cup (75 mL) of water into the large container.

Step 2 Bring the water to a boil on the hot-plate.

Step 3 Slowly add 2 cups (300 mL) of sugar, mixing gently with the stirring rod.

Step 4 Add one teaspoon of vanilla extract.

Step 5 Add a pinch of salt.

Step 6 Cook the candy, heating the mixture to a slow boil. Stir constantly and be careful that the mixture does not boil over.

1. While the candy is cooking, let's decide whether to make vanilla-flavored or chocolate-flavored candy. What do you think would be best? Why?

It is necessary, for the success of this activity, that half of the teams decide to make vanilla and half decide to make chocolate candy. From experience, this is the usual decision made by the students. However, you may have to use your influence to insure this distribution. The reasoning, and the answer to the question of "Why?" is that in any experiment with two choices, both methods are employed equally so that the results can be compared.

Step 7 The teams making chocolate candy should add three teaspoons of cocoa to their mixture and stir gently.

2. How do you decide when the candy has cooked long enough?

Someone may know that a drop of syrup is dropped into a glass of water. When the drop remains a lump instead of being stringy, the candy is cooked.

3. In this experiment, do you think that the candy should be cooled slowly or quickly?

Again, it is necessary, for the success of the activity, that at least one batch of chocolate and one batch of vanilla candy be cooled slowly and that one batch each be cooled quickly. The decision is usually reached by the students. If not, talk about the nature of an experiment to influence a change in their decision.

Step 8 For the candy to be cooled slowly, turn off the hot-plate and let the candy sit quietly.
For the candy to be cooled quickly, pour the mixture into a pie tin and place the tin on the bed of ice in the basin.

Step 9 Plan to continue this activity later in the day or the next day. The candy should not be disturbed until all batches have reached room temperature. It is essential to avoid moving or shaking the candy during the cooling process. This means no tasting, yet.

Part B

When all the batches of candy have cooled to room temperature, place them on the table so everyone may observe their appearance.

1. How would you describe the texture of the different batches of candy?

The students should note the candy cooled quickly in the pie tins has a fine texture. They may describe its appearance as "sugary," "sandy" or "speckled." The candy which cooled slowly in the beakers may be described as "lumpy," "chunky" or "big pieces."

2. What do you think caused the differences in the textures? Did the cocoa make the chocolate candy lumpy?

Students should reach the conclusion that fast cooling produced small grain sizes and that slow cooling produced larger grains or crystals. The cocoa had nothing to do with the grain size because the vanilla candy which cooled slowly is also lumpy.

3. How many different kinds of candy have been made?

Four kinds: sandy vanilla, lumpy vanilla, sandy chocolate and lumpy chocolate.

4. If you were going to open a candy store, could you invent

some descriptive names to help sell your candy? Place your names in the chart below:

Texture / Composition		Cooling Rate: Fast	Cooling Rate: Slow
Recipe	Vanilla		
	Chocolate		

Urge your students to create some imaginative names which emphasize the composition and the texture. Some names which have been suggested might appear on the chart as follows:

Heavenly Cream Candy	*Chunk Ice Candy*
Smooth Midnight Fudge	*Rocky Road Fudge*

After you have completed your chart, ask your teacher if you can eat the candy. Does it taste as good as implied by your names?

The answer is probably "No." If you try to improve the quality of the candy by using a regular fudge recipe, the difference in texture is lost.

Part C

A small collection of igneous rocks will be distributed by your teacher. These rocks were formed by cooling from hot molten liquid.

1. How could you arrange the rocks into two groups?

Some students will pair off the two light-colored rocks and the two dark-colored rocks. Others may pair off

the two sandy (fine-textured rocks) from the two coarse-textured rocks.

2. What is the basis of your classification?

   If the groups are based on color, the students should realize that they are basing their classification on composition. If the groups are based on texture, the students should realize that they are basing their classification on the cooling history (origin) of the rocks.

Geologists have given your rocks the following names:

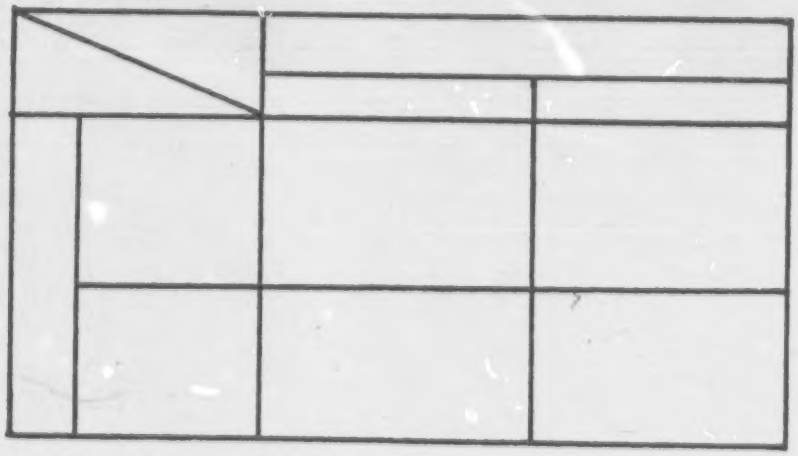
Granite = coarse-grained igneous rock composed of light-colored minerals

Gabbro = coarse-grained igneous rock composed of dark-color minerals

Rhyolite = fine-grained igneous rock composed of light-colored minerals

Basalt = fine-grained igneous rock composed of dark-colored minerals

3. Can you make a classification chart for these rocks? Complete the chart below:



Answer:

Texture / Color		Cooling Rate	
		Fine-grained	Coarse-grained
Composition	Light-colored Minerals	Rhyolite	Granite
	Dark colored Minerals	Basalt	Gabbro

Review Questions

1. How did the rate of cooling affect the texture of the candy?
2. How did the composition affect the texture of the candy?
3. How do you think the rate of cooling affects the composition of igneous rocks?
4. How do you think the rate of cooling affects the texture of igneous rocks?
5. What was the basis for classifying the four kinds of igneous rocks?

The Ice Age Puzzle

Adapted from an activity in
Earth Science Curriculum Project,
Investigating the Earth,
Boulder, Colorado, 1965

by
Victor J. Mayer

Imagine a giant grinder made of ice several thousand feet thick churning slowly over the earth. Plucking, scraping, and grinding along. Huge sheets of continental ice and the smaller valley glaciers completely changed the landscape they traversed. The landscape of half the world has been modified by the last great glacial advance.

Perhaps you do not live in an area that has been glaciated. Nevertheless, the methods of interpretation and gathering data used to work out the history of a glaciated area also apply to places where other kinds of erosional agents have been dominant.

This investigation concerns an area that was formerly covered by part of a continental ice sheet. In this investigation you will learn how to work out a past sequence of events by using information obtained by observation.

Objectives

When you have completed this activity you will be able to:

1. Develop a profile and cross section from a map.
2. Interpret features that are of glacial origin.
3. Determine the direction in which a glacier moved.

Materials

Colored pencils
Graph paper
Ruler

Procedure

Figure 1 is a map of a glaciated area. Note the scale of the map and the principal physical features of the land. Scattered across the map are Xs indicating the high points on the landscape and their elevations. Several of these points are

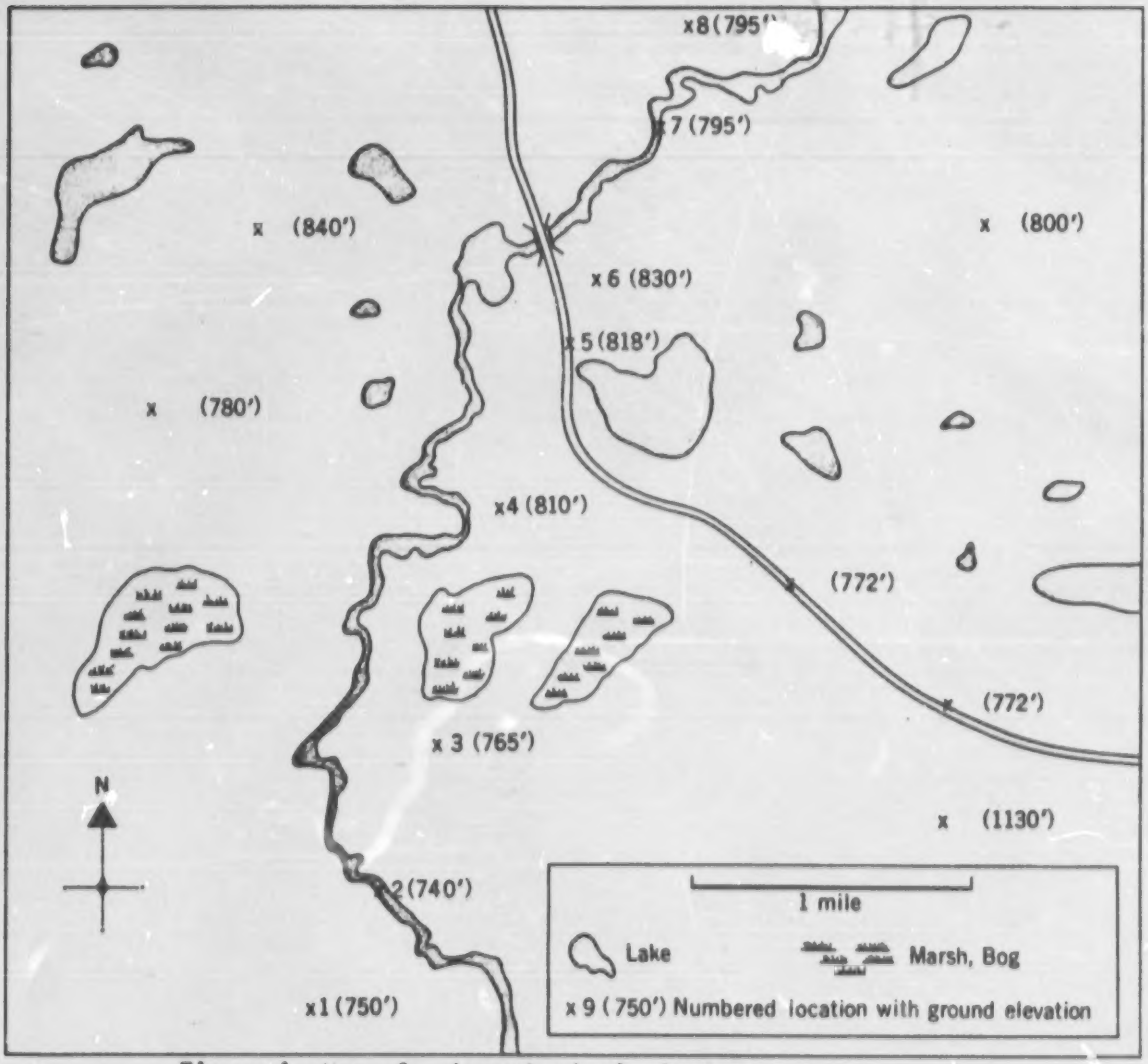


Figure 1 Map of a hypothetical glaciated area.

numbered. For numbered localities additional information is given in the accompanying data table. The points represent road cuts, stream banks, or drill holes where we can get a glimpse of the structure beneath the surface.

1. Draw a straight line connecting numbered localities (one through eight) on the map.

2. In the middle of a sheet of graph paper, draw a straight horizontal line slightly longer than the line connecting the numbered localities on the map. This is the line along

which you will draw a profile. The map of this strip of land is a plane view similar to what you would see from an airplane. On the graph paper you will be making a cross section (a side view of what occurs below the surface).

3. Let the horizontal line on the graph paper represent an elevation of 700 feet. Place points along the line which correspond to the correct relative positions of the numbered localities (one through eight).

4. Through these points draw light vertical lines. Using a scale of one centimeter = 25 feet, plot the elevation of each locality on its own line and then connect the elevation points. You now have a profile of the surface--an outline showing the shape of the land along this strip.

5. At each locality make a column about six millimeters wide beginning at the ground surface and extending downward. On this column plot the information from the data table for each locality. Use a color scheme or abbreviations for the rock and soil types. Be sure to include a legend so others will understand your drawing.

6. Note that there are two kinds of till distinguished by their color. Which till layer is apparently older? What is the evidence that a considerable amount of time elapsed between deposition of the two layers?

7. Recalling what you have learned about glaciers, what sequence of events would explain this?

8. At localities 5, 6, 7, and 8 the bedrock has been scarred by grooves. What probably produced these grooves? On the map, plot an arrow showing the direction of the grooves at the localities where they have been found.

9. Referring to your profile, with which till are the south-trending grooves associated?

10. How do you explain the absence of south-trending grooves at localities 7 and 8?

11. Notice the lakes on the map. How do you interpret the fact that they are lined up in a northwest-southeast-trending belt or zone?

12. With which till does this pattern of lakes appear to be associated?

13. South of the lakes are two marshes. How do these marshes

fit into your interpretation of the sequence of events in this area?

14. Summarize the interpretations you have made in connection with the foregoing questions into a logical history of the glacial activity in this area.

Table of Rock Descriptions From Surface Downward

Location 1. Elevation 750 feet; MINE SHAFT
weathered gray outwash (5 feet thick)
unweathered gray outwash (5 feet thick)
weathered reddish outwash (20 feet thick)
bedrock

Location 2. Elevation 740 feet; STREAM BANK
weathered gray outwash (5 feet thick)
unweathered gray outwash (5 feet thick)
weathered reddish outwash (21 feet thick)
bedrock (7 feet exposed)

Location 3. Elevation 765 feet; TEST BORING FOR A BUILDING
weathered gray outwash (5 feet)
unweathered gray outwash (10 feet thick)
weathered reddish till (12 feet thick)
unweathered reddish outwash (5 feet thick)
bedrock

Location 4. Elevation 810 feet; TEST BORING FOR MOTEL
weathered gray till (10 feet thick)
unweathered gray till (50 feet thick)
weathered red till (20 feet thick)
unweathered red till (5 feet thick)
bedrock

Location 5. Elevation 818 feet; ROAD CUT
weathered gray till (6 feet thick)
unweathered gray till (50 feet thick)
soil (2 feet thick)
weathered red till (20 feet thick)
unweathered red till (3 feet thick)
bedrock; grooves on surface are north to south

Location 6. Elevation 830 feet; SAND BANK
weathered gray till (10 feet thick)
unweathered gray till (65 feet thick)
weathered red till (20 feet thick)
unweathered red till (3 feet thick)
bedrock with grooves trending south

Location 7. Elevation 795 feet; STREAMBANK
weathered gray till (5 feet thick)
unweathered gray till (15 feet thick)
bedrock with grooves trending southwest

Location 8. Elevation 795 feet; BULLDOZED BANK
weathered gray till (5 feet thick)
unweathered gray till (13 feet thick)
bedrock with southwest grooves

Using a Sandwich to Understand Superposition

This activity has been adapted from the author's article which appeared in Teacher, April, 1980, v. 97, p. 54-57

by
Maurice L. Schwartz

Introduction

In this activity you will begin by making some sandwiches. We will think of the various sandwich materials as representing various kinds of sedimentary rocks. Can you think of ideas and things we can do with the sandwich to show some ideas of geology?

Objectives

When you have completed this activity you will be able to:

1. Tell how the age relations of a series of sedimentary rocks can be determined.

2. Describe how sedimentary rocks may be folded and faulted.

3. Explain how the origins of two kinds of igneous rock can be distinguished.

Materials

Each person needs:

Paper plate
Slice of white bread
Slice of light brown bread
Slice of dark brown bread
Knife or tongue depressor
Grape jelly
Chunky peanut butter

The teacher will also need:

Large kitchen knife (optional)

Electric soldering iron

Two tablespoons for serving the jelly and peanut butter

Paper towels

Procedure

Everyone is going to make a sandwich. We will think of the sandwich materials as being rock materials. In order for everyone to relate their sandwich to the geologic ideas, all the sandwiches must be made in the same way. Please follow the instructions.

Distribute the materials to each student. When the jelly and peanut butter are served, put about a tablespoon of each on the plates, not on the bread. The soldering iron should be plugged in so it will be heated when needed later in this activity.

1. Below are some rock names. After these names, write the name of the kind of sandwich material which seems to fit best:

   White sandstone =

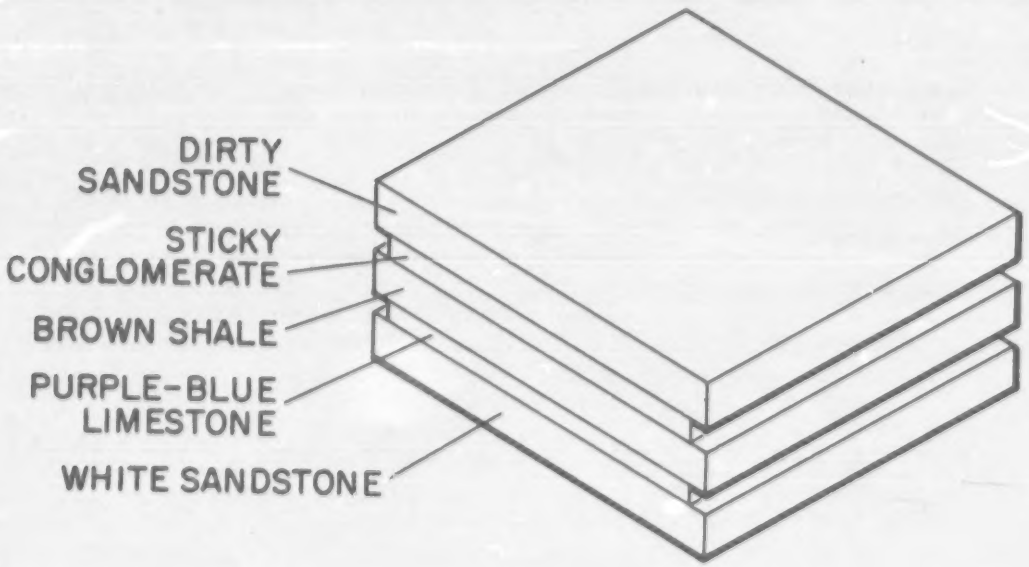
   Dirty sandstone =

   Brown shale =

   Purple-blue limestone =

   Sticky conglomerate =

2. Put the white sandstone on the paper plate and spread onto it the purple-blue limestone, place the brown shale on top of the limestone. Spread the sticky conglomerate on top of the brown shale. Put the dirty sandstone on top. Your sandwich should look like this. (Do not turn it over.)



3. Answer these questions:

(a) Assuming that it took about five minutes to build the sandwich, which is the oldest layer? Why?

Answer: The white sandstone because it was put down first. It is on the bottom; everything else came after it.

(b) Which is the youngest layer? Why?

Answer: The dirty sandstone is the youngest because it was put on top and was the last layer to be added

(c) What is the relative age of the brown shale layer?

Answer: It is between the age of the dirty sandstone and the white sandstone because it is in the middle.

(d) If a person spent five minutes making the sandwich but worked slowly at the start and worked faster at the end, could the age of the brown shale be exactly 2 1/2 minutes younger than the white sandstone? Why?

No. The speed of building was not the same. It might be three minutes younger because the person worked slower at the beginning.

(e) Remembering that the rate of building may vary greatly, how could the age of the brown shale be described most accurately?

Answer: The brown shale is younger than the layer below it (the purple-blue limestone) and is older than the layer above it (the sticky conglomerate).

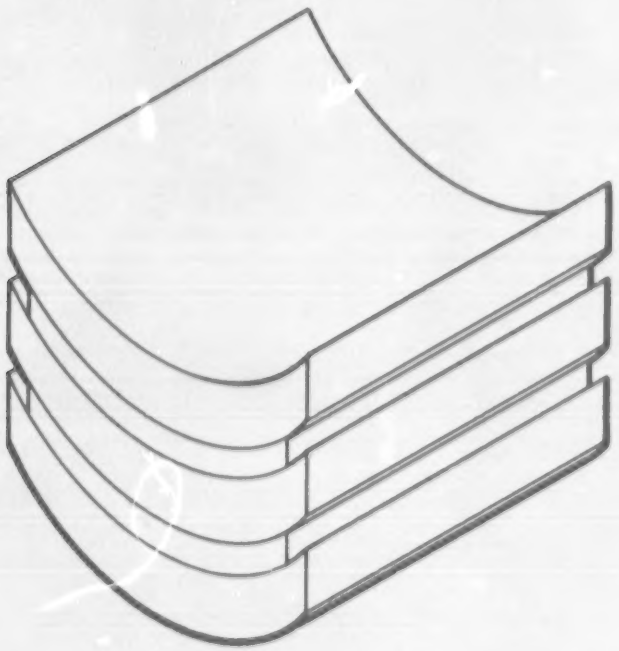
(f) In summary, write a general rule for the age of a given layer. Assume that (1) the layers were deposited in order, one after the other, and (2) the layers have not been turned over.

Answer: Students may express this idea differently. The layers on top are the youngest and those on the bottom are the oldest. A given layer is younger than any of the layers below it and older than any of the layers above it. Tell your students that this idea is expressed by the Law of Superposition which applies to sedimentary rocks.

(g) Write here the name of the law which states the age relations of rocks in a sedimentary series. (Your teacher may furnish this name for you.)

Answer: Law of Superposition

4. Gently fold your sandwich to form a trough or valley. It should look like the figure below. In geology, the structure is called a SYNCLINE.



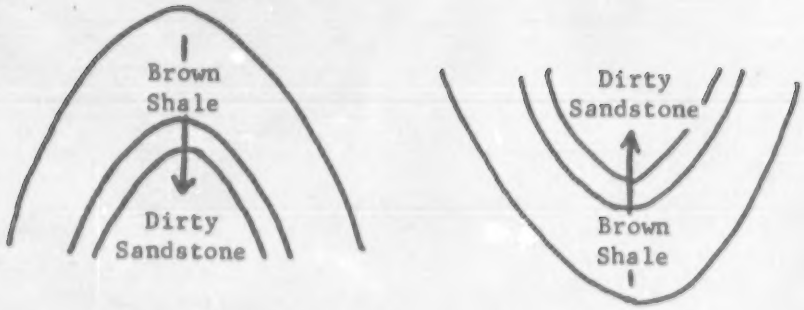
If you tilt your folded sandwich so that the valley dips either away from you or towards you, it is a model of a PLUNGING SYNCLINE.

(a) If you ate all the high parts of the folded sandwich representing a plunging syncline, would the rock in the center be older or younger than the rock on either side?

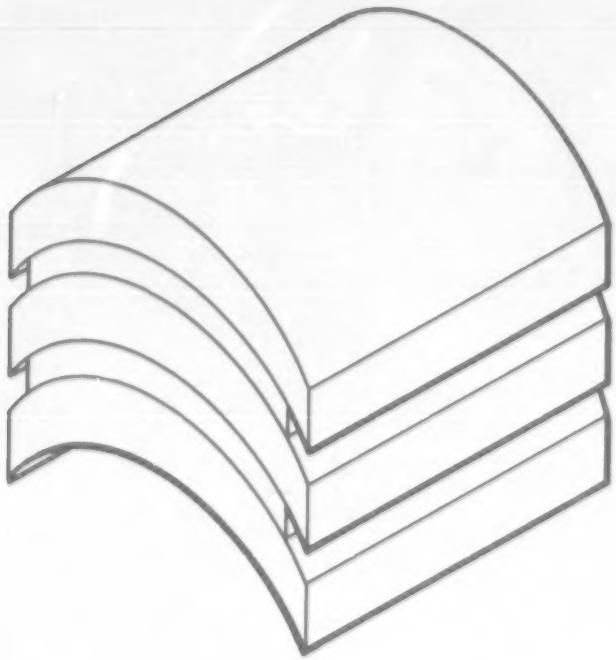
Answer: Younger

(b) Sketch the pattern of the top view of the rock layers if your plunging syncline were eroded (eaten) to a flat surface. Show with an arrow the direction of the plunge (the downward direction of the tilt of the valley).

Answer:



5. Gently fold your sandwich to form a ridge or elongate hill. It should look like the figure below. In geology, this structure is called an ANTICLINE.



If you tilt your folded sandwich so that the top of the ridge (the crest) or hill dips either away from you or towards you, it is a model of a PLUNGING ANTICLINE.

(a) If you ate all the high parts of the folded sandwich representing a plunging anticline, would the rock in the center be older or younger than the rock on either side?

Answer: Older

(b) Sketch the pattern of the top view of the rock layers if your plunging anticline were eroded (eaten) to a flat surface. Show with an arrow the direction of the plunge of the anticline.

Answer:

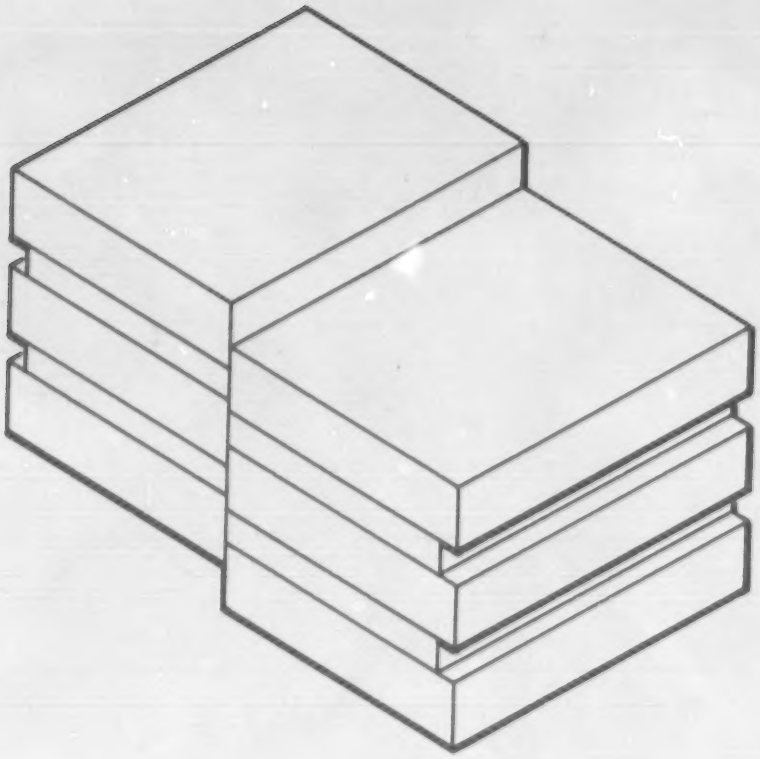
6. Cut your sandwich in half with a knife (or tongue depressor).

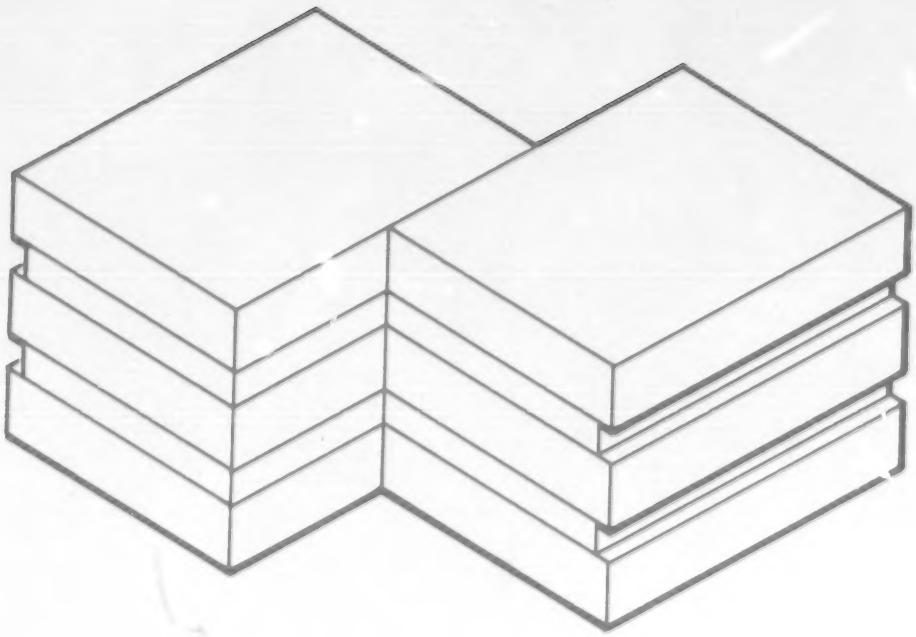
(a) If you hold the two pieces as shown in the diagram below, this is a model of a VERTICAL FAULT. What was the relative movement of the two parts?

Answer: The left side has moved up relative to the right side or the right side has moved down relative to the left side.

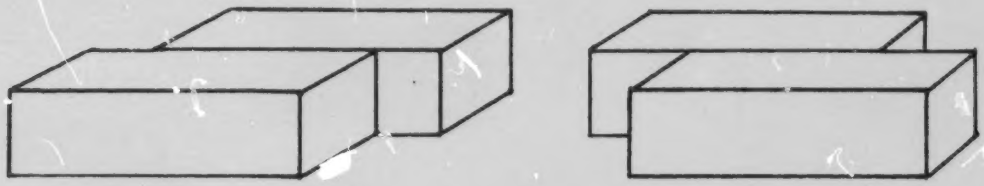
(b) If you hold the two pieces as shown in the diagram below, this is a model of a LATERAL FAULT. What was the relative movement of the two parts?

Answer: The right side has moved away from the viewer, or the left side has moved towards the viewer.





(c) The diagrams below show two lateral faults from a different view. Using arrows, show the direction of relative movement.



Answer:

These faults are named by asssuming you are located on one block and looking across the fault at the other block. They are called LEFT LATERAL FAULT and RIGHT LATERAL FAULT. The San Andreas fault in California is a right lateral fault.

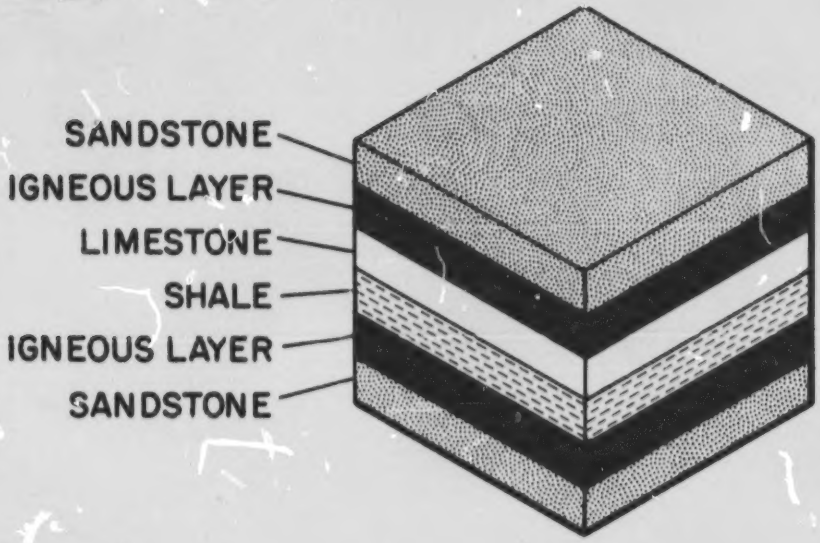
Which is which in the diagram?

Answer: The left lateral fault is shown by the diagram on the right and the right lateral fault is shown by the diagram on the left. The direction of the relative movement is designated by imagining you are standing on one side of the fault, looking across it, and describing in what direction the other side has moved.

7. Sometimes hot, molten lava flows out onto the surface of the land and is later covered with sediment which becomes sedimentary rock. At other times, hot molten rock (magma) will squeeze in between layers of sedimentary rock below the earth's surface. The magma is said to be intrusive. In both cases, when the molten rocks cool and crystallize they form igneous rocks. The diagram below is an example of the section of rocks which might be seen in a road-cut or building excavation.

(a) How could you determine whether the igneous layers formed from a lava flow or from an intrusive magma?

Answer: The students really do not have enough information to answer this question, but they should be encouraged to think about it. Some may know that lava cools more quickly than an intrusive magma so that the igneous rock from the lava should have more of a fine-grained texture.



This would be a good answer. After the students have run out of ideas, perform the following demonstration for them:

Take two layers of bread, held like a sandwich, and push the not soldering iron in between the two layers for a few moments to cause some toasting and burning of the bread. Then, keeping the sandwich in a horizontal position place the soldering iron on top of the upper surface of the top piece of bread, toasting some of this surface. After removing the soldering iron, place a third piece of bread on top of the other two. Keeping them together as a unit, pass the three pieces of bread around the class so that students may examine them.

(b) Which of the operations performed with the soldering iron resembles an intrusion and which resembles a lava flow.

Answer: The insertion between the layers resembles the intrusion. Lay the soldering iron on the top of the sequence resembles a lava flow.

(c) Examine the bread used in the demonstration. How can you tell whether an igneous rock layer found between sedimentary layers, formed from a lava flow or from an intrusive magma?

Answer: The effects of the heat of an intrusive magma should be seen on both the underlying and overlying rocks. The effects of the heat of a lava flow should be seen only on the underlying rocks because the overlying rocks were not present. The overlying rocks are younger and were formed after the lava had cooled.

The final part of this activity is to dispose of your sandwich without being wasteful. What do you think should be done with it?

Review Questions

1. What is the law of superposition?

2. How do the ages of the rocks in the center of an eroded anticline differ from those of an eroded syncline?

3. How are the relative movements of faults described?

4. How may an igneous rock layer in a sequence of sedimentary rocks be identified as having been formed by a lava flow or an intrusive magma?

Using Seismology to Learn About the Earth

by
Robert A. Christman, 1980

Introduction

Do you know what facts geologists use to postulate what the earth's interior is like? The interior cannot be observed. The deepest mines or drill holes only go down a very short distance in comparison to the earth's radius. Indirect evidence must be found to learn about what occurs at depth.

Objectives

Upon completion of this activity, you should be able to:

1. Tell how the velocity of earthquake waves varies with the kinds of earth materials through which they pass.

2. Explain how the velocity of the first wave of the Alaskan earthquake can be determined.

3. Describe how the kinds of rocks beneath the earth's surface may be postulated by studying data obtained from earthquakes.

Materials

A pencil
Ruler
Some earth science reference books

Procedure

Let's calculate how long it might take an earthquake wave to travel from Prince William Sound, Alaska, to Bellingham, Washington. The distance is 2080 km. The time depends on the speed (velocity) of the wave. This depends on the kind of material through which the wave passes. Approximate velocities through some common materials are as follows:

Salt water = 1.5 km/second
Sediment = 2.0 km/second
Granite = 6.0 km/second
Basalt = 7.0 km/second
Peridotite = 8.0 km/second

The formula is T=D/V (Time equals the distance divided by the velocity).

(a) If the wave traveled through salt water, how much time would it take?

Answer: 1387 seconds (2080 : 1.5 = 1386.66)

(b) If the wave traveled through sediment on the ocean bottom, how much time would it take?

Answer: 1040 seconds

(c) If the wave traveled through bedrock composed of granite, how much time would it take?

Answer: 347 seconds

(d) If the wave traveled through bedrock composed of basalt, how much time would it take?

Answer: 297 seconds

(e) If the wave traveled through bedrock composed of peridotite, how much time would it take?

Answer: 260 seconds

2. Next let's find out how long the wave actually took to travel from Alaska to Bellingham. From seismic data it was determined that the first strongest shock occured at Prince William Sound. The Greenwich meridian time was 3:36 and 13 seconds on the morning of March 28, 1964. This is abbreviated as 03:36:13 GMT. Its arrival time in Bellingham can be determined from the seismogram.

Figure 1 is an exact reproduction of part of the seismogram recorded by the seismograph at Bellingham. The time marks are recognized easily in the upper half of the record, prior to the arrival of any shock waves. After they arrived, the movement was so intense that very little can be recognized in the lower half of the record. From data on other parts of the seismogram, the time can be determined. The times are given for three of the marks on the left side of the figure. The horizontal distance between two time marks represents 60 seconds.

(a) Determine as accurately as possible the exact time in hours, minutes and seconds when the first wave arrived. To find the number of seconds, you need to use a ruler or to make a scale on a piece of paper. You need to determine what time is represented by the distance (less than 60 seconds) between the last time

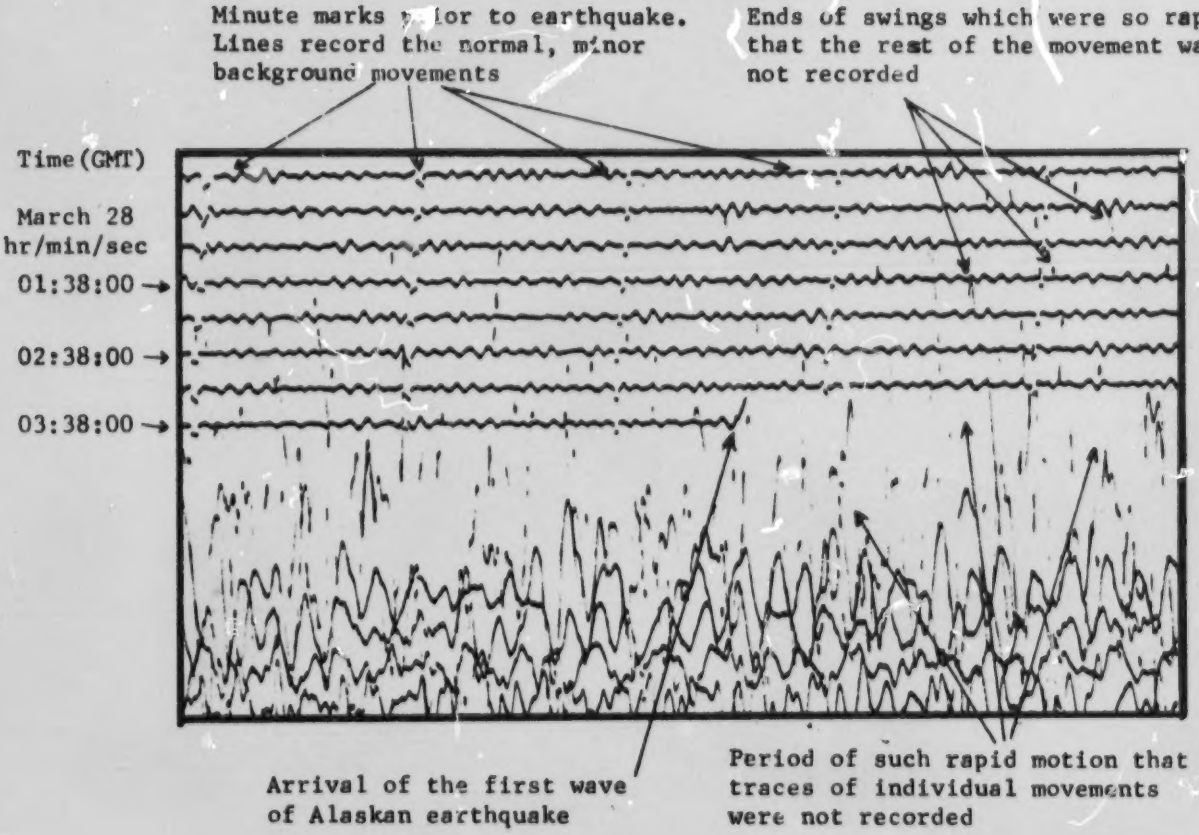

Minute marks prior to earthquake. Lines record the normal, minor background movements
Ends of swings which were so rapid that the rest of the movement was not recorded
Time (GMT)
March 28
hr/min/sec
01:38:00
02:38:00
03:38:00
Arrival of the first wave of Alaskan earthquake
Period of such rapid motion that traces of individual movements were not recorded

Figure 1 Exact copy of a portion of the Bellingham seismogram of the Alaskan earthquake showing the arrival of the first wave.

mark and the first earthquake movement which was recorded.

Answer: 03:40:34 The students should be able to determine that the number of seconds is slightly greater than 30 because the distance is greater than half of the distance between two time marks. Answers of 35 and 40 seconds are acceptable.

(b) Knowing the origin time and the arrival time, how many minutes and seconds did it take the earthquake wave to travel from Prince William Sound to Bellingham?

Answer: 4 minutes and 20 seconds (03:04:34 minus 03:36:13)

(c) How long did it take in seconds? (You need to convert the minutes to seconds)

Answer: 261 seconds (Four minutes = 240 seconds; 240 + 21 seconds = 261)

3. Let's see what we can learn by comparing the data from questions #1 and #2.

(a) Did the earthquake wave travel from Alaska to Bellingham through the ocean water near the earth's surface or did it travel through bedrock?

Answer: Its speed indicates that it went through bedrock. If the wave had traveled through salt water or sediment it would have taken much longer.

(b) Through what kind of material did it probably travel?

Answer: Peridotite. This is the only material listed whose calculated time of 260 seconds agrees with the actual travel time of 161 seconds.

(c) What kind of rock is this? If you do not know, find out about it in a reference book or dictionary.

Answer: Peridotite is an igneous rock composed of olivine and dark colored minerals. It does not contain quartz or feldspar which are common minerals in granite. It is most similar to basalt, except that basalt usually contains some feldspar.

4. How deep below the earth's surface would this wave have traveled? The best way to find the answer is to make a

diagram to scale. This has been done in Figure 2. The earth's radius at 45° north latitude is about 6,367 km. (This is an average of 6,378 km at the equator and 6,357 km at the poles.) The angle between lines drawn from the earth's center to Bellingham and Prince William Sound is about 18°. The surface distance between these two points is 2080 km.

(a) If the earthquake wave traveled in a straight path, what would be its average depth? (Measure the depth shown in Figure 2.)

Answer: 70-80 km. This is an estimate, so the answers will vary.

(b) Would the rock at this depth be considered part of the crust or part of the next deeper layer which is called the mantle? You will need a resource book to find out how thick the crust is under the ocean.

Answer: Rock at a depth of 70-80 km would be part of the mantle. The oceanic crust is usually considered to be about 5 km thick. The crust under the continents is thought to average about 40 km thick.

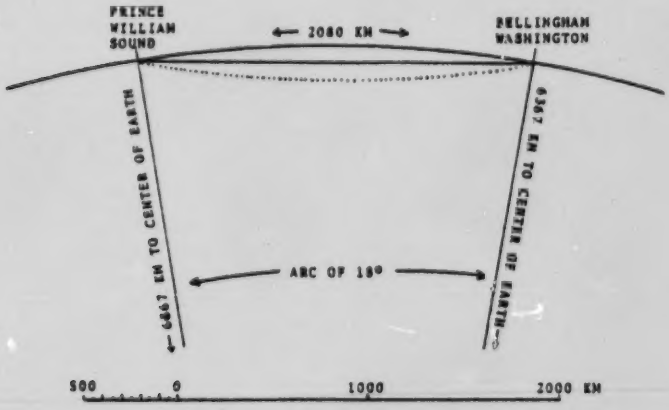


Figure 2 The relationship between the surface distance and the chord distance between Prince William Sound and Bellingham, WA

(c) Based on this kind of evidence geologists postulate that the rock in the upper part of the earth's mantle is composed of peridotite. How would you go about obtaining evidence on what kind of rock occurs at greater depths?

Answer: Study arrival times and determine the velocities of earthquake waves which were recorded at seismograph stations farther from Alaska. These will have traveled through the earth at greater depths.

Note: This activity neglects an important idea regarding the path which earthquake waves take. Because earthquake waves travel faster at greater depths, it is believed that the path of the wave, arriving first, actually is deeper, such as the one shown by the dotted line in Figure 2. It is difficult to determine the exact amount of bending. However, you should mention this complication. You might be asked questions about the distance. Because 2080 kms is the distance measured along the earth's surface, students determine how much difference this would make. The chord distance is about 12 km shorter than the surface distance. However, if the wave followed a curved path, going to a greater depth, the distance traveled might actually be nearly the same as the surface distance.

Review Questions

1. How do the velocities of earthquake waves vary depending upon whether the waves travel through salt water, sediment or bedrock?

2. How are velocities of earthquake waves determined?

3. What kind of rock probably occurs in the upper mantle?

4. How might the composition of other parts of the earth interior be discovered?

Extensions

1. Using resource books, find out what has been postulated to be the structure of the earth. Knowing how the information can be obtained on the nature of the materials of the earth's interior, you may have a better idea of how correct these ideas might be.

2. What was the local time of the earthquake in Alaska if the Greenwich time was 03:36:13? To determine this, you need to know that Prince William Sound is at about longitude 150° west and Greenwich is at 0°. Every 15° of longitude represents a time difference of one hour.

Travel Time: Earthquake Waves and Horses

by
Robert A. Christman, 1980

Introduction

When an earthquake is felt, everyone asks, "How far is it to where the earthquake occurred?" For some people this is a question of curiosity or concern for friends. For scientists it is a question of collecting scientific information. If the earthquake occurs in an unpopulated area, no one can give firsthand information. The best information is obtained from seismograms recorded at seismograph stations. Do you know how the distance to an earthquake can be found by studying a seismogram?

Objectives

Upon completion of this activity, you should be able to:

1. Tell how differences in time may be used to determine the distances traveled by horses in a horse race or shock waves in an earthquake.

2. Describe how the P and S waves can be recognized on a seismogram.

3. Explain how a travel-time curve may be used to find the distance to an earthquake.

Materials

A pencil
A ruler

Procedure

This exercise begins by considering a make-believe horse race. The ideas developed will help you understand how data on the distances traveled by earthquake waves may be obtained.

1. Figure 1 represents two photographs taken at a horse race. Each horse reached the 500-meter mark at different times, as is shown by the clock.

   (a) How long did Prince take to run the 500 meters?

   Answer: 40 seconds

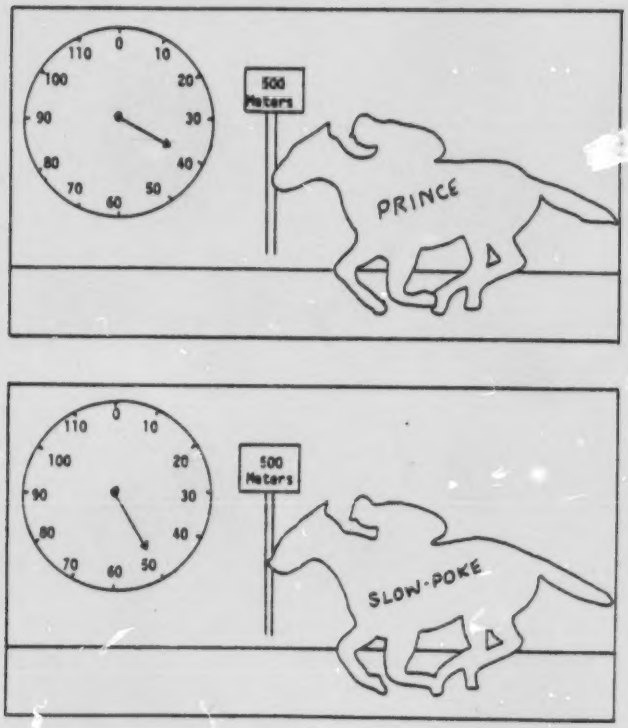
   (b) How long did Slow-Poke take to run the 500 meters?

   Answer: 50 seconds

   (c) What was the difference in their times?

   Answer: 10 seconds

Figure 1 Travel Time: Earthquake Waves and Horses



2. Figure 2 represents two other photographs taken of the same race. These photographs were taken opposite the 1000-meter mark.

(a) How long did Prince take to run the 1000 meters?

Answer: 80 seconds

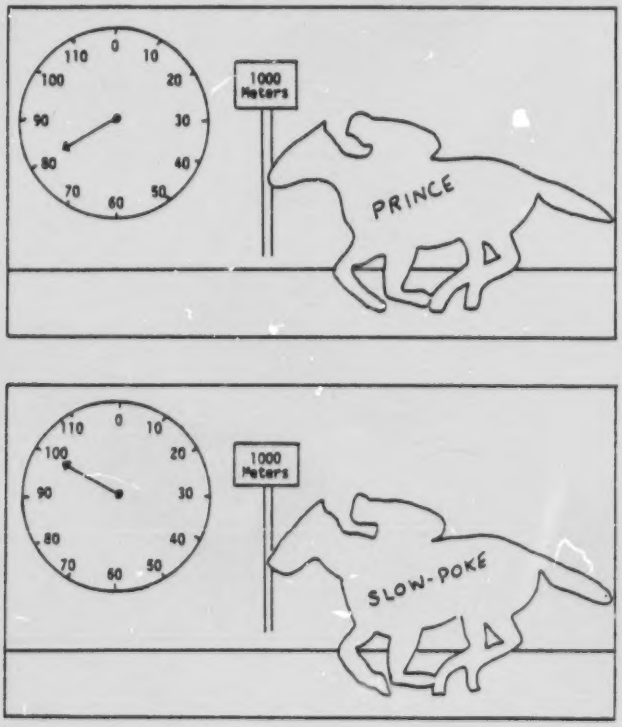
(b) How long did Slow-Poke take to run the 1000 meters?

Answer: 100 seconds

(c) What was the difference in their time?

Answer: 20 seconds

Figure 2 Travel Time: Earthquake Waves and Horses



3. Figure 3 represents two more photographs taken of the same race. The marker is missing so the distance is not known.

(a) How long did Prince take to run this unknown distance?

Answer: 60 seconds

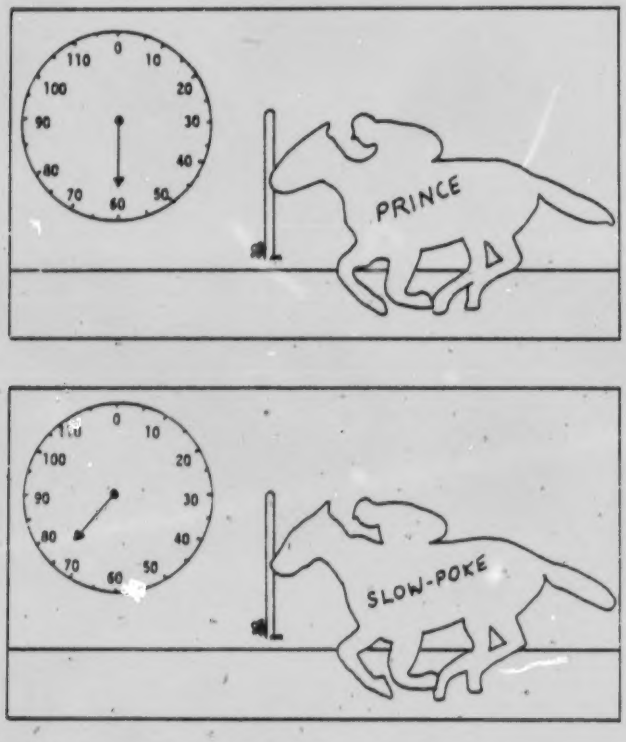
(b) How long did Slow-Poke take to run this unknown distance?

Answer: 75 seconds

(c) What was the difference in their times?

Answer: 15 seconds

Figure 3 Travel Time: Earthquake Waves and Horses



4. Think about how the difference in time varies in these three sets of photographs.

(a) Have the horses shown in figure 3 run 1) less than 500 meters, 2) more than 1000 meters or 3) some distance between 500 and 1000 meters?

Answer: Some distance between 500 and 1000 meters

(b) What is the exact value of the unknown distance of figure 3?

Answer: 750 meters

(c) How did you determine this?

Answer: Because the time difference of 15 seconds was exactly half way between the time difference of 10 seconds for 500 meters and 20 seconds for 1000 meters, the distance must be half way between 500 and 1000 or 750 meters.

5. You were able to determine the unknown distance because the relationships between the numbers were easy to understand. In arriving at these answers the assumption is made that the horses ran at constant speeds. However, the main idea is that the distance can be determined from the time difference. This would apply even if the time difference was an odd value like 17 1/4 seconds. To avoid math problems with fractions, distances for various times can be easily determined if a graph is used. Figure 4 is a graph of this horse race. Both horses start at zero distance at

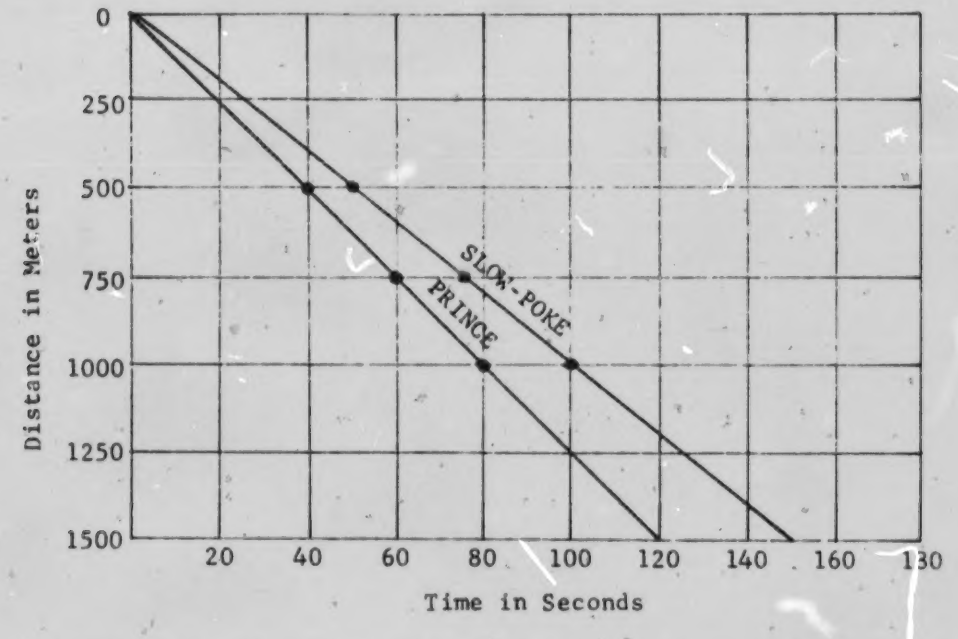


Figure 4 Graph of the horse race between Prince and Slow-Poke

zero time. At 500 meters Prince has run 40 seconds and Slow-Poke has run 50 seconds for a time difference of 10 seconds. At 750 meters Prince = 60 seconds, Slow-Poke = 75 seconds with a time difference of 15 seconds. At 1000 meters Prince = 80 seconds, Slow-Poke = 100 seconds with a time difference of 20 seconds.

(a) With increasing distances of travel, how does the time difference change?

Answer: The time difference becomes progressively larger.

(b) If at some place of the race the time difference was 30 seconds, how far would the horses have run?

Answer: 1500 meters

(c) If at another point of observation time the difference was 23 seconds, approximately how far were the horses from the start?

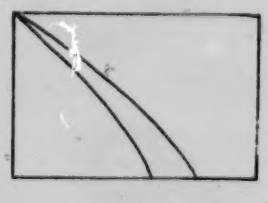
Answer: 1150 meters

How did you determine this?

Because of the materials to follow, it is important that the teacher develop with the students the method, given here, for obtaining the distance from the graph. Lay a strip of paper along the bottom scale (Time in Seconds) and mark off two points on the paper to represent the time difference. In this question, the marks should be 23 seconds apart. Keeping the paper parallel to the base, the strip is moved up and down along the graph to find the place where the two lines are exactly 23 seconds apart. The distance is read on the scale on the left.

(d) If the horses became tired and ran slower by the same relative amounts, how would this change the graph?

Answer: Instead of being straight, the lines would be curved. They might look like this:



When an earthquake occurs, it generates different kinds of waves. These are transmitted through rock in different ways giving them different speeds. As the distance of travel becomes greater, one kind gets ahead of the other kind, just as Prince got farther ahead of Slow-Poke. With distance they slow down, so the lines on the graph are curved.

The two most important kinds of waves are P waves (Primary) and S waves (Secondary). Both originate at the same point of the earthquake but the P wave (like Prince) travels faster than the S wave (like Slow-Poke). If the time difference is known at a particular place, a travel-time graph can be used to determine the distance to where the earthquake occured.

Figure 5 is an exact reproduction of part of the Bellingham seismogram of the 1964 Alaskan earthquake. The time is recorded by the tic marks; some of these are labeled on this figure. This seismogram shows the movements caused by several earthquakes. The one recorded in the upper part of the figure shows best. It is an aftershock which occurred somewhere in Alaska after the main earthquake. If you count the time spaces, you can determine that the P wave (shown by the first movement) arrived between 10:09 and 10:10. The arrival of the S wave is recognized by the change in pattern between 10:13 and 10:14.

6. What is the time difference between the arrival of the P and S waves as actually recorded on the Bellingham seismogram? (Measure this on figure 5)

   Answer: 4 minutes. Coincidental, the time difference between P and S for this earthquake is exactly four minutes, which is an easy answer for students.

Figure 6 is a graph which shows the travel time for P and S waves traveling through the rocks between Alaska and Bellingham. Only part of the graph is shown. If the lines were extended upwards, they would meet at zero distance and zero. This graph is similar to the one showing the travel times for Prince and Slow-Poke.

7. How far away from Bellingham did this earthquake originate? (Use the time difference obtained in question #6. Mark this off on a strip of paper and determine where on the graph the P and S waves are exactly this distance apart.)

   Answer: 2260 to 2280 km. The main difficulty students may have in arriving at an acceptable answer is that some will read the vertical scale on figure 6 incorrectly. Each space represents 20 kilometers. Because the P and S lines are rather thick, students will disagree slightly as to where the lines are

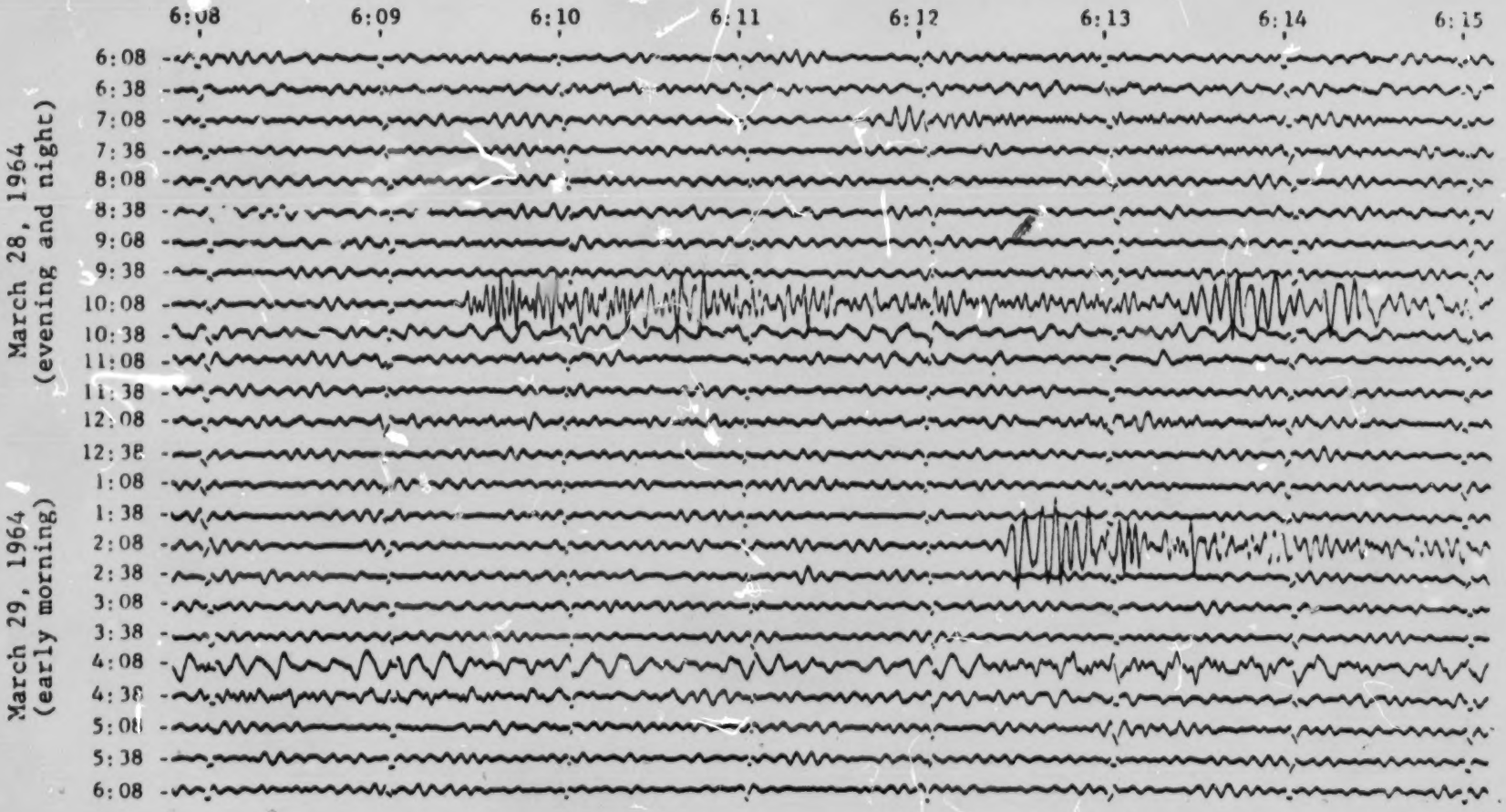


FIGURE 5 EARTHQUAKES ASSOCIATED WITH THE 1964 ALASKAN EARTHQUAKE

This is an exact reproduction of a small portion of the Bellingham seismogram for March 28-29, 1964. Although the recording was made as a single line on a rotating cylinder, this diagram only shows portions of this line. The time is indicated by "tic" marks. The ones near the edges are labeled.

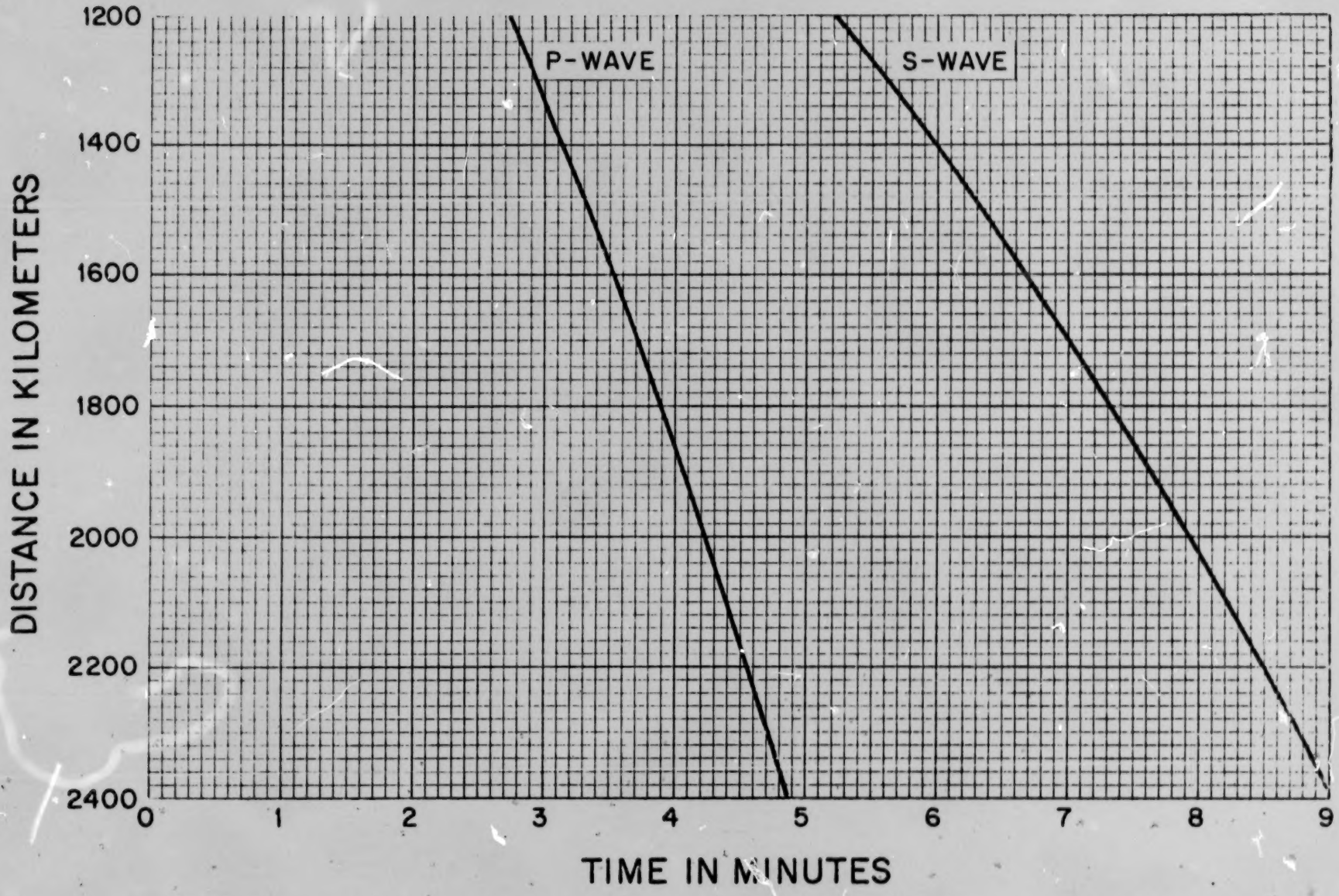


Figure 6 Travel time curves, specially prepared to be used for studying the Alaskan earthquakes on the Bellingham seismograms.

exactly 4 minutes apart. However, understanding the method is more important than having everyone obtain a particular value.

Review Questions:

1. How were the distances run by Prince and Slow-Poke determined by their running times?

2. How do the ideas about the race between Prince and Slow-Poke relate to the way earthquake waves travel?

3. Exactly how does a seismologist determine the distance to an earthquake by studying a seismogram?

Epicenters of the 1964 Alaskan Earthquake

by
Robert A. Christman, 1980

Introduction

After a large earthquake has occurred, geologists need to find its exact location. How can this be done? By talking to people, it might be very hard to decide where the ground shook the most. An earthquake might feel one way to a person sitting on a rock. The same earthquake might seem different to a person on the third floor of a building with a weak foundation. Also, the place of the strongest movement might be away from people. When an earthquake occurs in Alaska, the major shock often occurs far from villages or towns, so that there are no witnesses.

When an earthquake occurs, it releases energy which travels through the rocks as waves. To locate where the earthquake occured, one needs to find out where the strongest waves originated. A seismograph records these waves on a seismogram. By studying a seismogram, it is possible to learn about the magnitude of the earthquake and how far the waves have traveled. From this kind of information, one can determine where the earthquake took place.

Objectives

Upon completion of this activity, you should be able to:

1. Explain how a seismologist locates the epicenter of an earthquake.
2. Describe the distribution of the aftershocks associated with 1964 Alaskan earthquake.
3. Tell how the Alaskan earthquakes may be related to a subduction zone.

Materials

A pencil
Compass
Worksheets 1 and 2

Procedure

A seismologist can find the location of an earthquake by collecting data from seismograms. The times of arrival of two

different kinds of waves are found. These waves are called the primary (P) and secondary (S) waves. The P wave always travels faster than the S wave. Thus, the farther they travel, the farther they become separated. By determining how much the P wave is ahead of the S wave, the distance which they have gone may be found by using a chart. Using the distance as a radius, a circle can be drawn around the station on a map. The earthquake is then known to be located somewhere along this circle. Because some other information is usually available from news reports, only part of the circle may be drawn. However, it is important to note that this method does not determine the direction or exact location of the earthquake. Other information is needed.

To pinpoint the location, a seismologist collects data from many stations. If it can be determined how far the earthquake was from the other stations, circles can be drawn around each of these. The place where all the circles intersect on a map is the location of the earthquake. This point is called the epicenter. It is the point on the earth's surface directly above the place where energy was released below the surface by the earthquake.

1. Locate the epicenters of two Alaskan earthquakes. Use the data from Table 1 and use the map of Worksheet 1. When drawing the circles or arcs with a pencil compass, an accurate radius may be obtained by using the scale on both sides of zero on the map. As shown in Figure 1, the right side is used to measure multiples greater than 500 km and the left side is used to accurately scale off distances of less than 500 km.

Table 1. Distances from four seismograph stations to the epicenters of two aftershocks associated with the 1964 Alaskan Earthquake.

	Date & time*	Distance from Bellingham,WA	Distance from Edmonton, Can.	Distance from Pasadena, CA	Distance from Honolulu, Hawaii
1.	March 29 06 05 GMT	2280 km	2560 km	3600 km	3880 km
2.	March 29 04 12 GMT	1938 km	2025 km	3440 km	4420 km

*Greenwich Meridian Time

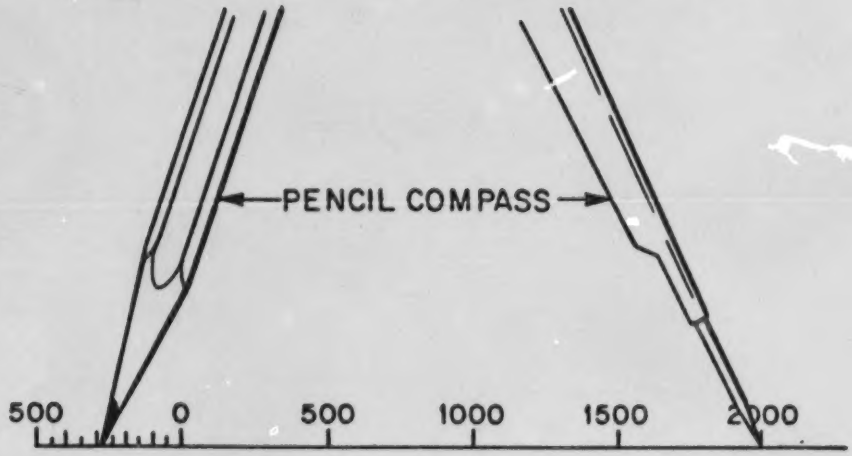
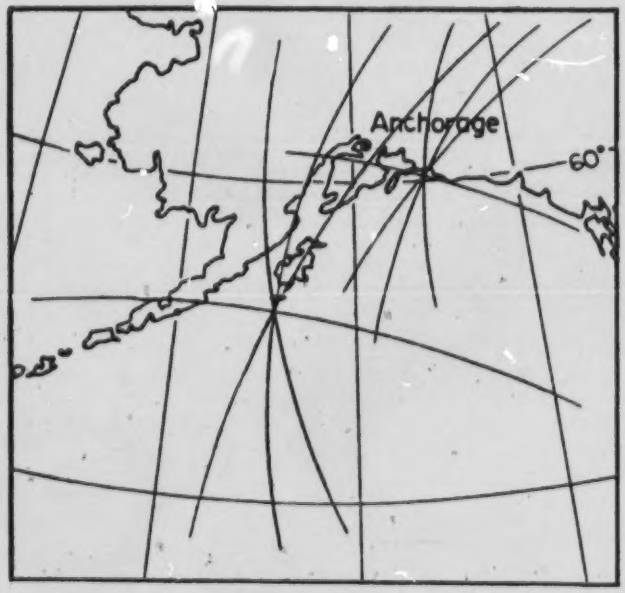


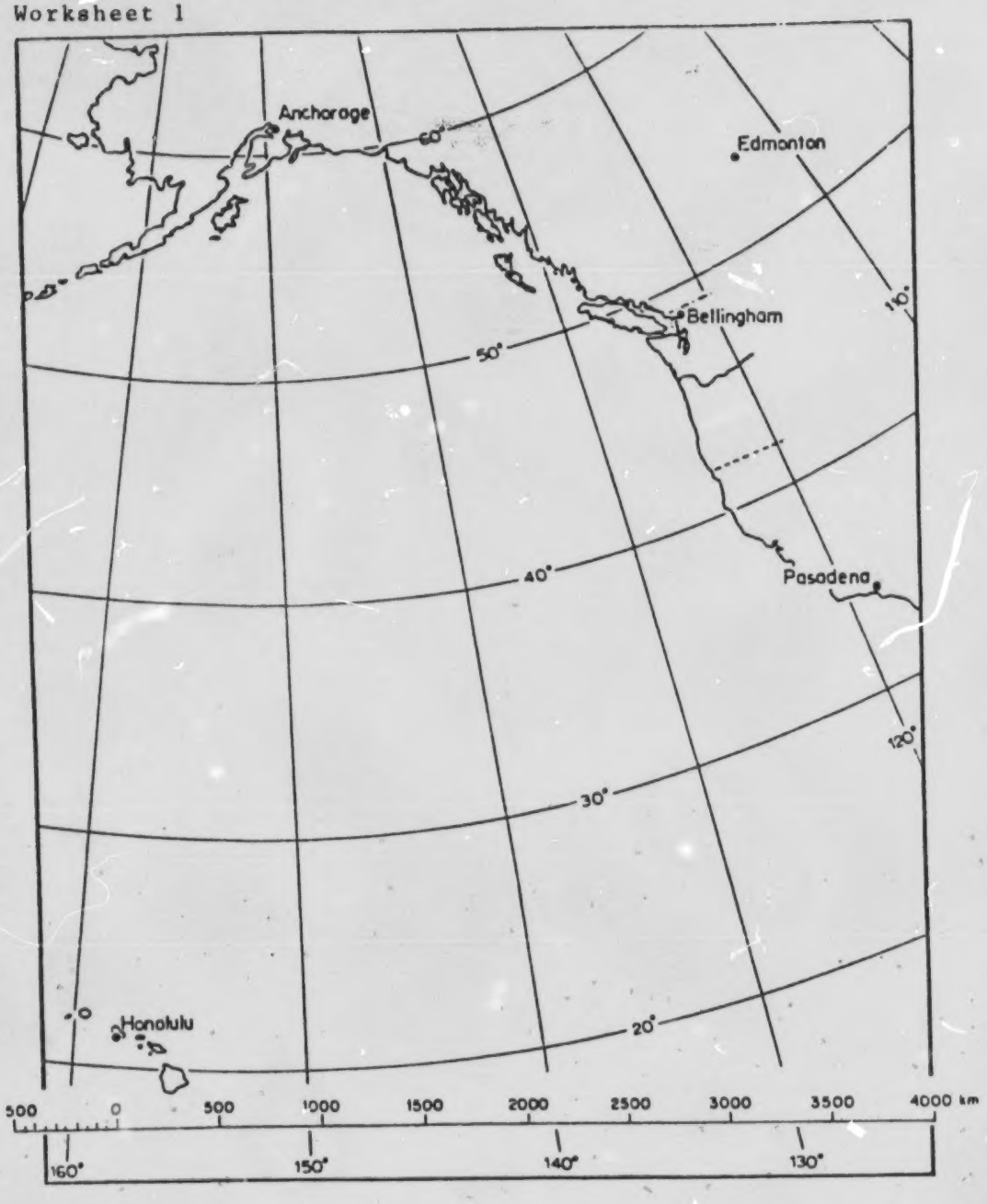
Figure 1 Compass is set at 2280 km. by measuring 2000 km. to the right of zero and measuring 280 km to the left.

2. Approximately how far and in what directions were these epicenters from Anchorage?



#1 is about 650 km to the SW and #2 is about 250 km to the SE. Exact positions are shown on the sketch map. The map of Worksheet 1 was especially drawn for this activity so that all distances from Anchorage are correct. Other maps cannot be substituted unless they are equi-distant projections.

Worksheet 1



Equidistant map centered on Anchorage

3. When you located the epicenters for two earthquakes in question #1, were you surprised by your results? Did you expect them to be so far apart and so far from Anchorage?

In this part of the activity, the epicenters of 25 earthquakes will be plotted to learn something about their distribution. These earthquakes are called "aftershocks" because they followed the main shock. Hundreds were recorded. Some of the strongest ones are listed in Table 2. If they had occurred by themselves, many of them would have been considered major earthquakes. Plot each of these on the map of Worksheet 2 using its latitude and longitude.

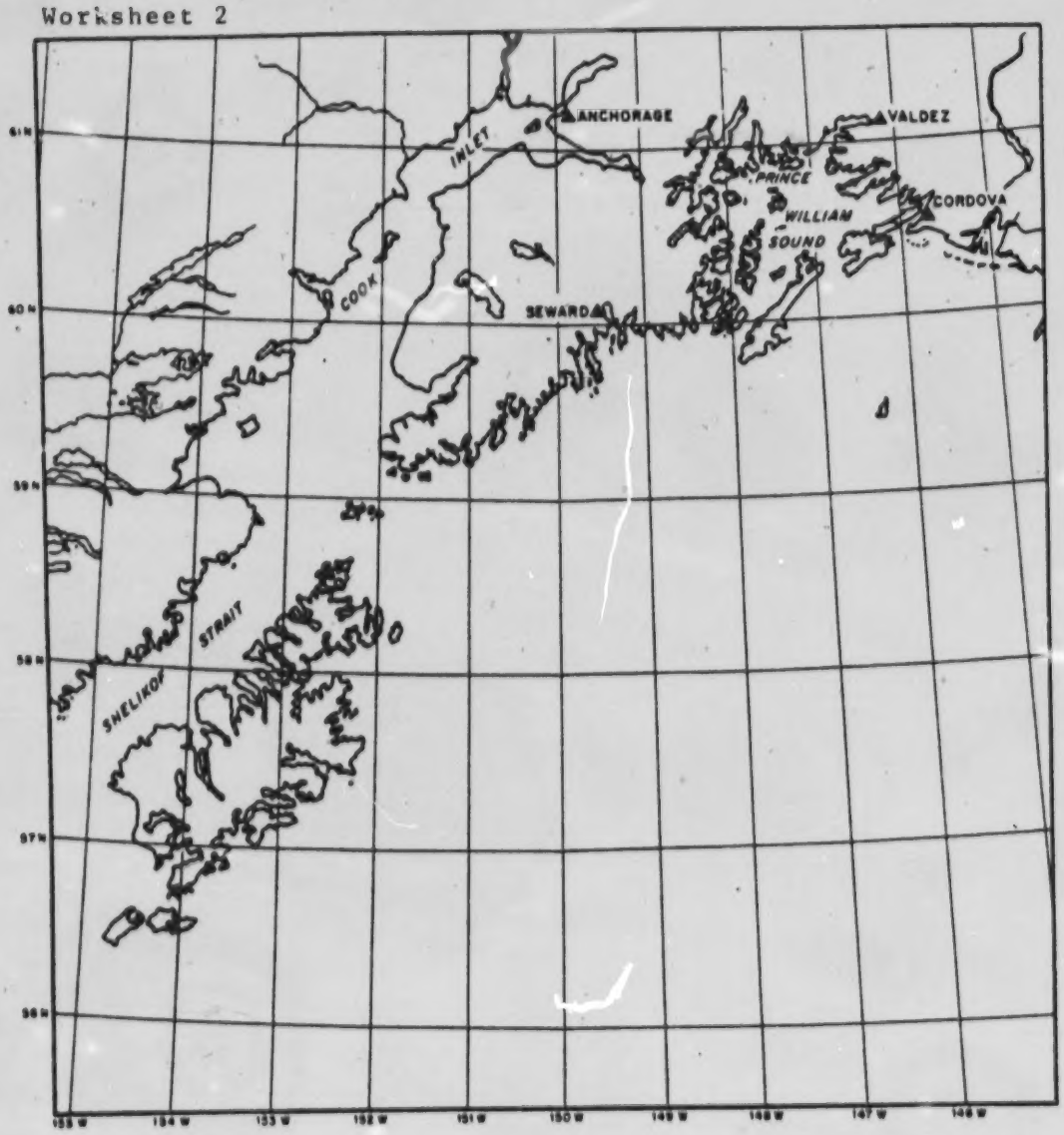
Table 2 Epicenters for some 1964 Alaskan Earthquakes

	Date	Time GMT Hour Min	Latitude	Longitude	Magnitude
1.	March 28	03 36	61.05N	147.50W	8.4
2.	March 28	06 44	58.3N	151.3W	6.1*
3.	March 28	06 54	58.8N	149.6W	5.7*
4.	March 28	07 31	57.3N	151.7W	5.3*
5.	March 28	08 46	58.0N	152.2W	6.5
6.	March 28	08 55	58.2N	149.4W	4.6*
7.	March 28	09 01	56.5N	152.0W	6.2
8.	March 28	09 53	59.7N	146.6W	6.2
9.	March 28	12 03	60.3N	146.6W	5.1
10.	March 28	12 21	56.5N	154.1W	6.5
11.	March 28	14 48	60.4N	146.5W	6.3
12.	March 28	14 49	60.4N	147.1W	6.5
13.	March 28	20 29	59.8N	148.9W	6.6
14.	March 29	01 10	59.9N	149.2W	5.2
15.	March 29	04 12	60.2N	145.4W	5.3*
16.	March 29	06 05	56.2N	154.2W	5.8
17.	March 29	10 08	60.0N	148.5W	5.2*
18.	March 29	11 57	57.9N	151.5W	5.0*
19.	March 29	16 18	60.3N	146.2W	4.9
20.	March 29	16 46	59.8N	147.0W	6.3
21.	March 29	16 53	60.4N	146.0W	5.0*
22.	March 30	02 18	56.6N	153.0W	6.6
23.	March 30	07 10	59.8N	145.9W	6.2
24.	April 3	22 34	61.7N	147.7W	6.0
25.	April 4	09 11	57.0N	152.8W	5.5

*Magnitudes by Coast and Geodetic Survey; all others from Pasadena, CA

Data from Preliminary Report, Prince William Sound Alaskan Earthquakes, March-April 1964: Coast and Geodetic Survey, April 1964.

Worksheet 2



MAP OF AREA SOUTH OF ANCHORAGE ALASKA

123

4. Describe in your own words the distribution of these epicenters.

They are randomly distributed in a broad band from near Valdez in the northeast to the southwest corner of the map. They form a zone which is nearly 700 km long and 200 to 300 km wide.

5. What was the sequence of these earthquakes in time? After the main shock (Epicenter #1) did the aftershocks occur in some kind of order, like a chain reaction of falling dominos?

No sequence is evident. The order seems random, even though this does not seem logical.

6. As shown in Figure 2, it is believed that a subduction zone occurs in a NE-SW trending direction of the coast. The Pacific Ocean Plate is believed to be slowly going down beneath Alaska. How might this explain the origin of the earthquakes?

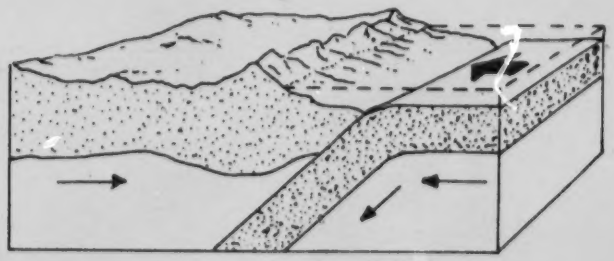


Figure 2: Schematic drawing showing the Pacific Ocean Plate being subducted beneath Alaska.

Although the details are very complex, students should be able to understand how earthquakes could be caused by the movements of the plates. In some areas the plates, rather than moving slowly and continuously past one another, become "locked" by friction. When they do move it is by a series of jerks (earthquakes) when the pressures for movement overcome the friction. Thus, earthquakes along a subduction zone have different intensities which are related to how much pressure has built up before rupture. They may be distributed over a large area of the subduction zone. A break in one place seems to trigger breaks in other parts of the zone. Although the concept of "epicenters" seems to imply a break at a single point, it would be more accurate to think of the breaks occuring along dipping planes.

Review Questions

1. How does a seismologist locate the epicenter of an earthquake by using data from seismograms from several different stations?

2. What was the distribution of the aftershocks?

3. How might the earthquakes be related to the subduction zone?

Density and What It Can Tell Us About The Structure of the Earth

by
Maurice Schwartz and Robert A. Christman
This activity is based on one titled,
The Size and Weight of the Earth
by Maurice Schwartz
which appeared in the
Washington Science Teachers' Journal,
Winter, 1980, Vol 20, No. 1, p. 7-9

Introduction

When scientists first calculated the density of the earth, they found that the earth was denser than any of the rocks found on its surface. How was the density determined? What ideas resulted from these calculations?

Objectives

Upon completion of this activity you should be able to:

1. Explain how density is determined.
2. Tell how density can be used to determine composition.
3. Describe the structure of the earth.

Materials

Each team will need the following items:

Clay balls prepared by the teacher
1000 mL (or cc) graduated cylinder (filled with water to the 500 mL level)
Thread, 5 pieces about 50 cm long
Balance scale (grams)
Rock samples of sandstone, granite and basalt

Prepare the clay balls by imbedding a steel or iron ball (2-4 cm in diameter) in the center of some of them. If the first part of the activity is done as a class inquiry, make three balls; one with the metal interior and two without, but of different sizes. If this is done with teams, make a pair of balls with and without the metal interior for each team. In both cases, make the clay ball with the metal interior slightly larger than the pure clay balls. The clay balls and rock samples must be smaller than the

diameter of the graduated cylinder so they can be lowered by thread into the water. However, do not make them so small that it will be difficult for students to make accurate measurements.

These items should be available in the science supply room. If you have only one set of equipment, the activity can be done as a class inquiry-demonstration. Preferably, with more equipment, the students can conduct their own inquiry independently in teams.

Procedure

1. Examine the clay balls by looking and handling them but without altering them in any way. Describe the balls, noting how they are similar and how they are different.

   Students should record that the clay balls appear to be similar in composition (clay) and shape. The sizes are slightly different. The larger one is heavier than the smaller one.

2. How could the differences be explained?

   The size difference is simply that some appear to consist of more clay. The weight difference might be related to the size. However, because the increased weight seems to be too great for the increased size, the heavier one may have a different composition or may have something heavier inside of it.

3. Without altering the clay balls, how could you express your observations about the differences in weight with figures or facts.

   The specimens could be weighed. However, because the relationship to size must be considered, the density is more important than the actual weight.

Because we are concerned with weight, mass, size, volume and density, these terms are explained here:

Weight is a measure of the gravitational attraction between two bodies. You would weigh less on the moon than on the earth because, though you remain the same, the gravitational pull of the moon is less than that on earth.

Mass is the quantity, or amount, of matter in something. Thus, the mass of an object does not change if you move it into different gravitational fields.

Size can be measured as length, area or volume.

Volume is the amount of space an object occupies. It can be expressed either as milliliters (mL) or cubic centimeters (cc).

Density is the mass per unit volume. For this exercise we will assume that the mass equals the weight and ignore the question of differences due to gravitational fields. Thus, density is the weight of something for its size.

Density is a concrete number (the density of iron is 7.6 gm/cc). Specific gravity is the weight of a substance compared to the weight of an equal volume of water. Because one cc of water weighs one gm, in the metric system density and specific gravity have the same value, except that specific gravity is an abstract number without units (the specific gravity of iron is 7.6).

4. Determine the density of the large and small clay balls. Use the balance to obtain their weight (or mass) in grams. To find the volume, tie a thread around a ball and lower it into the water in the graduated cylinder. Record the displacement of the surface level. Divide the volume into the mass to obtain the density. Complete the chart below:

	Mass	Volume	Calculated Density D = M/V
Small clay ball	_____gm	_____cc	_____gm/cc
Large clay ball	_____gm	_____cc	_____gm/cc

The density of the pure clay ball should be about 2.5 gm/cc. The density of the clay ball with the iron or steel ball should be considerably greater and will depend on the kind of metal and relative proportions of clay and metal.

5. Which of the following statements have you proven and why?

   A. The greater weight of the larger clay ball compared to the smaller one can be explained by the difference in sizes.

   B. The greater weight of the larger clay ball compared to the smaller one cannot be explained completely by the difference in sizes.

The answer is "B." If the increased weight of the larger ball were simply due to the larger amount of clay, the density of the two balls would be the same. Because the densities are different, the larger ball must have a different composition--it must have something heavier inside.

At this time, let the students break open the heavier clay ball to see what is inside of it.

6. Turning now to the earth, let's see how its density can be determined.

The size of the earth could be determined after the circumference was found. The circumference, or distance around the earth, was first calculated in 200 B.C. by Eratosthenes, a librarian in Alexandria, Egypt. He found the angle between the sun's rays and a vertical line at two cities, Alexandria and Syene, at exactly the same time. Knowing the distance between the two places and the angles, Eratosthenes was then able to arrive at a distance very close to the 40,000 kilometers that we now know as the earth's average circumference. The volume of the earth can be calculated as being 1.1×10^{27}cc. (The "$\times 10^{27}$" part of the number means that twenty-seven zeros are added to the number.)

It wasn't until much later that the mass of the earth was determined. In 1687 Sir Isaac Newton reported that "the force of gravity between any two bodies in the universe is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centers." This means that

$$F = G \times \frac{M_1 \times M_2}{d^2}$$

where F is the force, m_1 and m_2 are the masses of two bodies, d is the distance between their centers, and G is the gravitational constant. If G is known it is possible to determine the mass of the earth; because then each value in the above formula, other than one mass (that of the earth), can be put into the calculation to arrive at a solution.

The first person to determine the value of the gravitational constant (G) was Henry Cavendish. In a laboratory experiment, performed around 1798, he measured the gravitational attraction between very delicately balanced metallic balls. After this procedure was refined, it became possible to calculate the mass of the earth as being 6.0×10^{27}gm.

Using the figures above, calculate the density of the earth. (Use D = M/V and do not worry about the large numbers because the "10^{27}'s" cancel out.) What value did you obtain?

$$D = \frac{6.0}{1.1} = 5.5 \text{ gm/cc}$$

7. The three most common rocks found on the earth's surface (or near surface) are sandstone, granite and basalt. Using the same method as used for the clay balls, what are their densities?

Rock	Mass	Volume	Density
Sandstone	_____gm	_____cc	_____gm/cc
Granite	_____gm	_____cc	_____gm/cc
Basalt	_____gm	_____cc	_____gm/cc

The density of sandstone should be about 2.5; granite is about 2.7; and basalt is about 3.0. The exact values will vary. Because the students may have difficulty making accurate measurements, reasonable answers should be accepted. However, sandstone should be at the low end and basalt should be at the high end of the values.

8. Sedimentary rocks, like sandstone, cover 80% of the land surface of the earth. Continental landmasses are underlain by mostly granitic rocks. The "basement" (bottom) rock under the ocean floor is basalt. Do you think the earth is composed of these three kinds of rocks, with sedimentary rocks on the surface, granites under the continents and basalts extending to the center of the earth? Why do you think this?

No. The densities of these three kinds of rock are too low to explain the average 5.5 gm/cc for the earth.

9. How may the density of the earth be explained?

Like the clay ball with the steel ball as an interior, it is believed the earth has a metallic core. The density proves that the interior must be denser than 5.5 if the surface rocks are 3.0 or less.

Scientists believe that the core is composed of iron and nickel. Because many meteorites are composed of Fe-Ni, it is suggested that, if these are a common pair of heavy elements in the Universe, then they might also be an important pair in the earth.

Seismological techniques also indicate that the interior of the earth is dense and layered. These

studies suggest that a solid inner core (1,243 km thick) is surrounded by a liquid outer core (2,308 km thick) which in turn is surrounded by a thick layer of rocks (2,846 km) called the mantle. The earth's crust is usually considered to be 5 km thick under the ocean and 40 km thick under the continents.

As an extension, have students make a model or a drawing to show the structure of the earth. When the layers are drawn to scale, the students will be impressed with the thinness of the earth's crust. If the thickness of the crust is not exaggerated, it will be about the width of a pencil line on most drawings.

Ashfall in Washington--Courtesy of
Mount St. Helens

Adapted from an activity in
Mount St. Helens: Classroom Activities
Education Service District No. 112,
1313 N.E. 134th St., Vancouver, WA 98665

by
Robert A. Christman, 1980

Introduction

You have read about and seen pictures of the volcanic ash which fell on the state of Washington. The largest ashfall was the result of the May 18, 1980, eruption of Mount St. Helens. From the photographs and stories in the newspaper you might have thought that the entire state was ankle-deep in ash. Do you have any idea as to how much ash fell? Do you know how it was distributed?

Objectives

Upon completion of this activity you should be able to:

1. Describe the distribution of ash following the May 18 eruption.
2. Develop a theory for the reasons the pattern of distribution of the ash.
3. Tell how much ash fell.

Materials

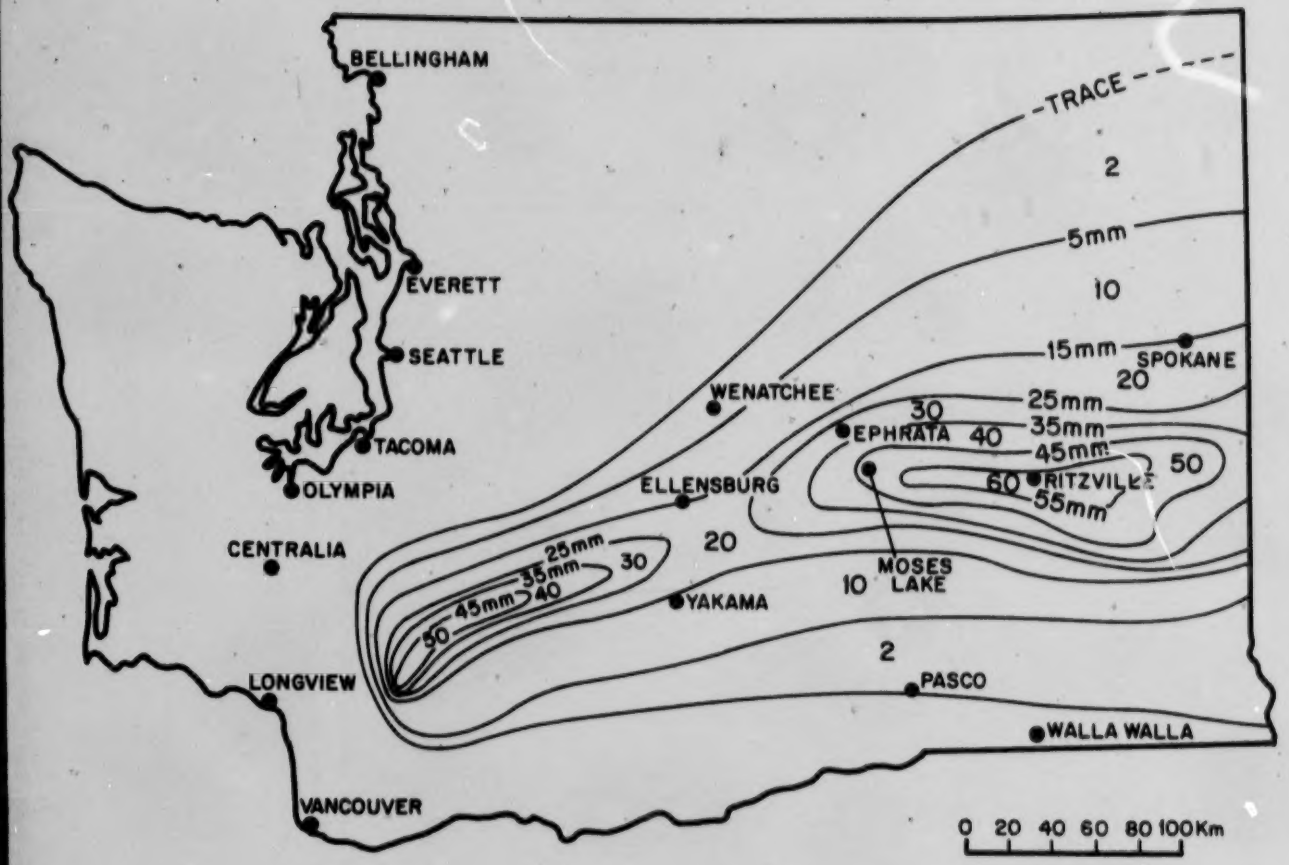
You will need a copy of the map showing the ashfall thicknesses. A calculator might be useful.

Procedure

Study the map showing the thickness of the ash from the May 18 eruption of Mount St. Helens. To understand the map you need to know that the winds in the Pacific Northwest generally blow from west to the east.

1. How can you tell where Mount St. Helens is located on the map?

By the pattern of the ash. It is located at the west



MAP SHOWING THE THICKNESS OF ASH FROM THE MAY 18, 1980 ERUPTION OF MOUNT St. HELENS
The thickness is shown by the contour lines. The numbers between the contour lines is the average thickness of the ash in the area between the contour lines.

end of the blanket of ash. This is east of Longview where the contour lines are close together and at the tip of the area with the largest amount of ash.

2. Based on the pattern of the areas of greatest ashfall, what were the wind directions?

   Adjacent to Mount St. Helens the winds blew the ash to the northeast. Further away the winds carried the ash in an east-northeasterly direction. When the ash clouds reached Moses Lake, the winds blew directly from the west to the east. This is shown by the fact that the area of greatest ashfall is distributed in an west-east direction.

3. Which areas received the largest amount of ash?

   The area around Ritzville received over 55 mm of ash with an average of 60 mm. Another area closer to Mount St. Helens received more than 45 mm of ash with an average of 50 mm.

4. How much ash fell in the area between Ellensburg and Yakima?

   Only about 20 mm.

5. The ash which fell in the Yakima area was partly the size of fine sand. The ash which fell near Ritzville was finer grained and was mostly the size of silt. If you think about an ideal case, what would you expect to be the distribution and size of the ash in the windward direction from an erupting volcano?

   The thickest deposits should be closest to the mountain. These would contain the coarsest material. Away from the volcano, the ash would become increasingly more fine-grained and the deposits would be increasingly thinner. Some of the finest ash might be blown high in the atmosphere. This might be carried a great distance; sometimes it is carried all the way around the earth.

6. What two reasons can you think of to explain why so much ash fell in the Ritzville area and why less ash fell in the Ellensburg/Yakima area? (The exact reason for the odd distribution is not known.)

   Maybe the eruption of Mount St. Helens produced a super abundance of silt-sized ash and a deficiency of sand-sized ash. Less ash fell in the Ellensburg/Yakima area simply because there was less of the sand-sized

material. The ash clouds carried great quantities of silt-sized material which was deposited in the Ritzville area.

A second possible explanation is that on the day of the eruption, the winds were blowing strongly and picked up speed in the Ellensburg/Yakima area. The winds were able, because of their speed, to carry the material which ordinarily would have been dropped. However, by the time the clouds reached the Ritzville area they diminished in strength. The decrease in speed caused large quantities of ash to be deposited.

7. Do you think that the amount of ash deposited next to the mountain is shown correctly on the map?

It probably is not exactly correct because on the northeast flanks of the volcano the deposits were much thicker than 50 mm. However, these would not show on the scale of this map. Also, their thickness was not known completely at the time this map was published.

8. Think about the differences between "zero" ash and a "trace" of ash. What does this suggest about how precisely the "trace line" is located on the map?

It would be very difficult to find enough facts to accurately tell the difference between "trace" and "zero" ash. Therefore, it is important to realize that the lines on the thickness map are approximately located.

9. The area receiving more that 5 mm of ash is approximately 54,500 km^2. The State of Washington is about 176,600 km^2. What percent of the state received more than 5 mm of ash?

Answer: 31% $\frac{54,000}{176,000} = 30.8\%$

10. The chart on the next page gives the sizes of the area which received various amounts of ash from the May 18 eruption. Complete the last two columns of the chart to determine the volume of ash in cubic kilometers.

11. What is the total volume of ash in cubic kilometers which fell on the State of Washington from the May 18 eruption? (Add the volumes obtained in the last column of the chart to obtain the total.)

Answer: 1.266 km^3 or rounded off to 1.3 km^3

Average amount of ash	Size of area	Amount of ash given in kilometres	Calculated volume of ash in cubic kilometres
2 mm	28,000 km^2	.000 002 km	.056 km^3
10 mm	25,000 km^2	.000 02 km	.250 km^3
20 mm	11,500 km^2	.000 02 km	.230 km^3
30 mm	6,500 km^2	.000 03 km	.195 km^3
40 mm	5,500 km^2	.000 04 km	.220 km^3
50 mm	4,500 km^2	.000 05 km	.225 km^3
60 mm	1,500 km^2	.000 06 km	.090 km^3

12. If you constructed a road with the ash which fell on Washington, how long would this road be in kilometers? Assume that the road will be 10 meters wide and 0.1 meter thick (10 centimeters). Use 1,300,000,000 m^3 as the amount of ash.

Answer: 1,300,000 km
Each kilometer of road would require 1000 m^3 of ash.
(1000 m x 10 m x 0.1 m = 100 m^3)
1,300,000,000 - 1000 = 1,300,000 km

13. If the distance from San Francisco to New York City is approximately 4000 km, how many roads could be built between these two cities with this ash?

Answer 325 roads (1,300,000 - 4000 = 325)

14. If the circumference of the Earth is about 40,000 km, how far would the road extend around the equator?

Answer: about 32 times (1,300,000 - 40,000 = 3.25)

15. Some of the newspapers and scientific reports state the amount of material erupted from Mount St. Helens on May 18 was one cubic kilometer. In this activity the calculations give the amount as 1.3 cubic kilometers. What reasons can you think of for this difference in values?

The measurements of the thickness of the ash fall were too few so that the lines and averages are only

approximate. When more facts are gathered the size of the area may be slightly different.

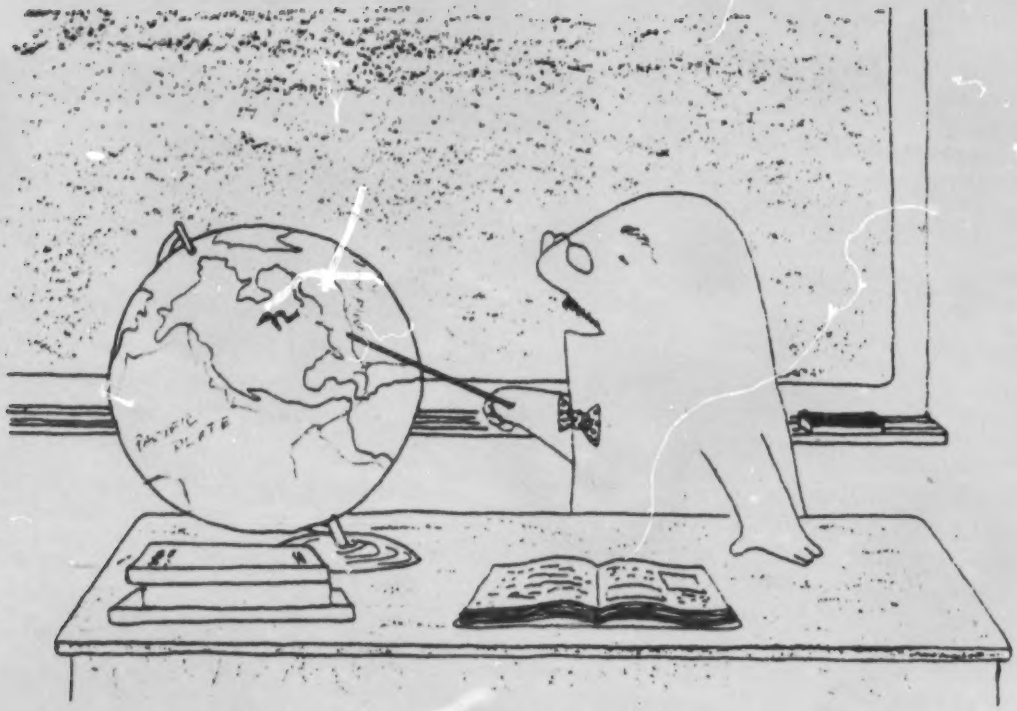
The measurement of ash thickness did not consider the "packing." Some of the ash further from the mountain was quite fluffy. Ash which was measured to be 45 mm thick in the Ritzville area might actually be less thick if it were compacted. The ash which fell nearer to the volcano and measured 45 mm thick was much coarser in size. The 45 mm there might represent more material than the 45 mm at Ritzville because the particles were more closely packed together.

16. People have wondered what to do with all the ash. What do you think will happen to it?

Some of the finer ash will be carried away by winds. Some will be carried away by running water and will be deposited as silt and sand behind the dams on the Columbia River. Most of it, however, will become part of the soil.

CHAPTER IV

PLATE TECTONICS



Movement Along The San Andreas Fault

by
John Steinback, 1979

Introduction

The San Andreas Fault System is a part of a worldwide system of faults, rifts, trenches, and mountains that outline the moving plates of the lithosphere. In particular, the San Andreas Fault System is part of the boundary between the North American Plate and the Pacific Plate.

Various techniques, including seismic surveys, laser measurements, and ocean floor dating of magnetic stripes have indicated that the western side of the fault is moving Northwest relative to the eastern side. The rate of movement has been determined to be about one centimeter per year over the past several million years in Northern and Central California.

Baja, California, and a sliver of California are drifting northwest with the Pacific Plate while the North American Plate drifts west.

Objectives

When you have completed this activity, you should be able to:

1. Describe the direction of motion of the North American and Pacific Plates.

2. Determine the future location(s) of the Point Reyes Peninsula (California-Baja California segment of the Pacific Plate) relative to the North American Plate.

3. Infer the probable "continental source" of the California-Baja segment of the Pacific Plate.

4. Determine relative plate movement over time when given rate of movement.

Materials

Topographic map: Points Reyes, California Quadrangle 7.5 minute quadrangle, United States Geological Survey.
Tracing paper
Scissors
World map (globe or Mercator projection)

Procedure

1. Locate the Point Reyes Peninsula on the Point Reyes Quadrangle. Locate the San Andreas Fault Zone, and notice that it runs northwest through Tomales Bay and into the Pacific Ocean.

2. Place a long edge of the tracing paper along the San Andreas Fault Zone and trace the outline of the Point Reyes Peninsula. Then cut out the tracing.

3. If the movement along the fault is one cm/yr, how long would it take for the Point Reyes Peninsula to move one km to the northwest?

4. Place your cut-out of Point Reyes on the Quadrangle directly on top of Point Reyes. Then slowly and carefully slide it along the San Andreas Fault in a northwest direction until the cut-out no longer touches the North American Continent. The straight edge of the paper will be in Tomales Bay.

5. Using the map scale, determine how many kilometers the peninsula has moved.

6. If the rate of movement is one cm/yr, how long would it take the Point Reyes Peninsula to cover the distance you determined in step number 5.

7. What type of landform will the Point Reyes Peninsula have become?

Review Questions

1. Describe the direction of movement along the San Andreas Fault in the vicinity of Point Reyes.

2. Describe the projected, long-term future of the Point Reyes Peninsula.

3. We have projected movement along the San Andreas Transform Fault Zone into the future, now let us project into the past. Look at the world map, and, in your mind, slide the Point Reyes--California--Baja "sliver" southeastward along the San Andreas Fault. To what land mass might this "sliver" have been attached?

Extension

1. Refer back to review question number three. Using a world map, determine the distance the California---Baja "sliver" must have traveled from its previous point of attachment.

2. Using the rate of one cm/yr, calculate the length of time it has taken Point Reyes to get to its present location.

3. Refer to a geologic time chart in your text and determine the geologic period in which the point Reyes--California--Baja Peninsula "sliver" was attached to a different section of mainland.

The density of continental rock is generally less than the density of the rock making up the ocean floor. You can view the continents as "floating" on a layer of greater density rock. This would be similar to a block of wood floating on water or a block of iron floating on mercury.

The continents appear to be carried along with the movement of the lower layer of higher density rock upon which they rest. When a continental plate moves into an ocean plate, the ocean plate, being of greater density, tends to be subducted under the continental plate. An ocean trench is the place where this subduction occurs.

4. The Point Reyes Peninsula is a northern extension of the California---Baja Peninsula "sliver" of the Pacific Plate. Locate this on a world map. If the Point Reyes Peninsula and the rest of the Pacific Plate continues to move in a northwesterly direction, describe what will happen to it when it reaches the trench near the Aleutian Islands. (HINT: Point Reyes is part of a continental rock "sliver" on the predominantly oceanic Pacific Plate.)

Imaginary Continents: A Geologic Puzzle

Developed for the
NAGT Crustal Evolution Education Project (CEEP)

by
Rolland B. Bartholomew, Gene Lene, Douglas Smith and Bill White
published in the Journal of Geological Education,
Vol. 26, p. 195-197, 1978

Introduction

Imagine you are looking at the earth from a spaceship. Does it look like South America and Africa were once joined together? Would knowing the ages of the rocks on the two continents help you to decide?

Geologists have been trying to find out if these continents were joined together long ago. They are making many comparisons including evidence from fossils, glacial features, and rock ages. In this activity you will be comparing the ages of rocks on two imaginary continents. You are going to play geologist. Were the imaginary continents once one giant continent? Like other puzzles, the solution may surprise you!!

Objectives

When you have completed this activity, you should be able to:

1. Find the age of a rock by using a radioactive decay curve.
2. Decide whether or not two imaginary continents might have been joined at one time.
3. Estimate the unknown ages of rock units by inference.

Materials

Scissors
Pencil

Procedure

1. Look at the shape of the imaginary continents on the worksheet. Do they look like they would fit together in any way?

2. Determine the ages of the different rock units by completing the table below. You can find the age of each rock unit by using the graph in Figure 1 as explained by your teacher.

Rock Unit	Radioactive Element	% of Original Mass Remaining	Age of Rock in billion of years
A	U^{238}	60	____ x 10^9 years
B	U^{235}	25	____ x 10^9 years
C	Rb^{87}	97.5	____ x 10^9 years
X	U^{235}	12.5	____ x 10^9 years
Y	U^{238}	95	____ x 10^9 years
Z	Th^{232}	87.5	____ x 10^9 years

Table I. — Ages of the Rock Units

3. Using the age of the rocks recorded in Table I, draw dashed lines between the continents on the worksheet 1 to match rocks of similar age.

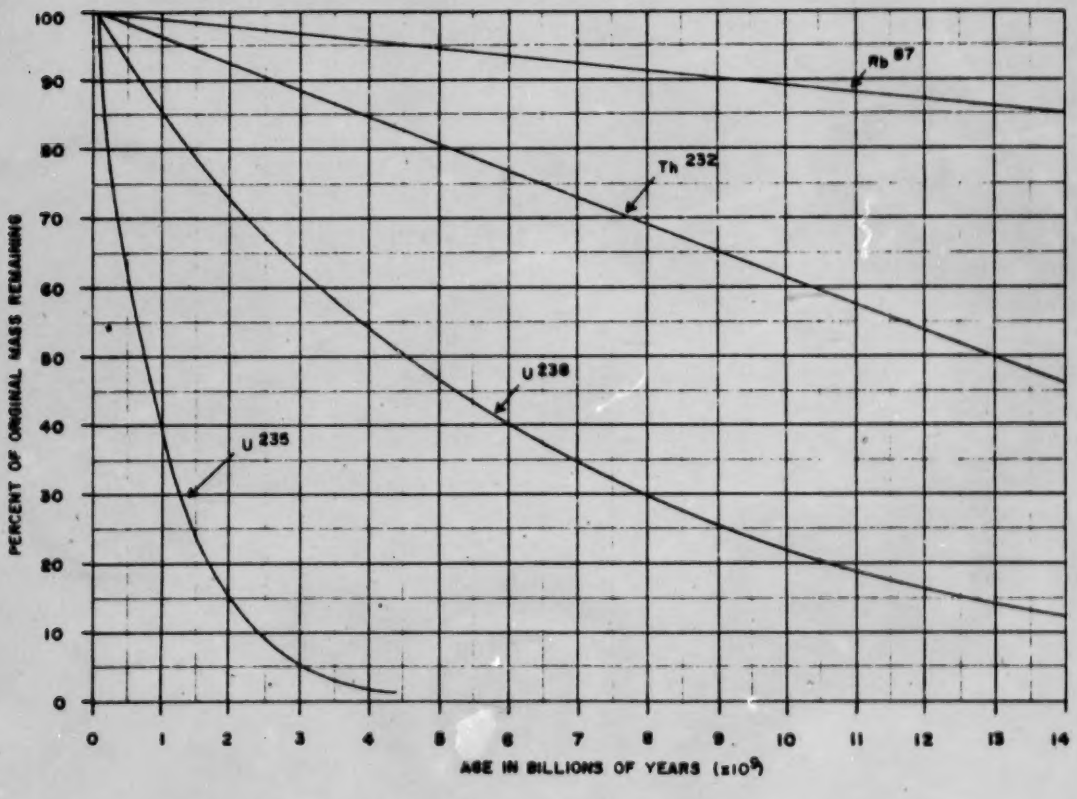
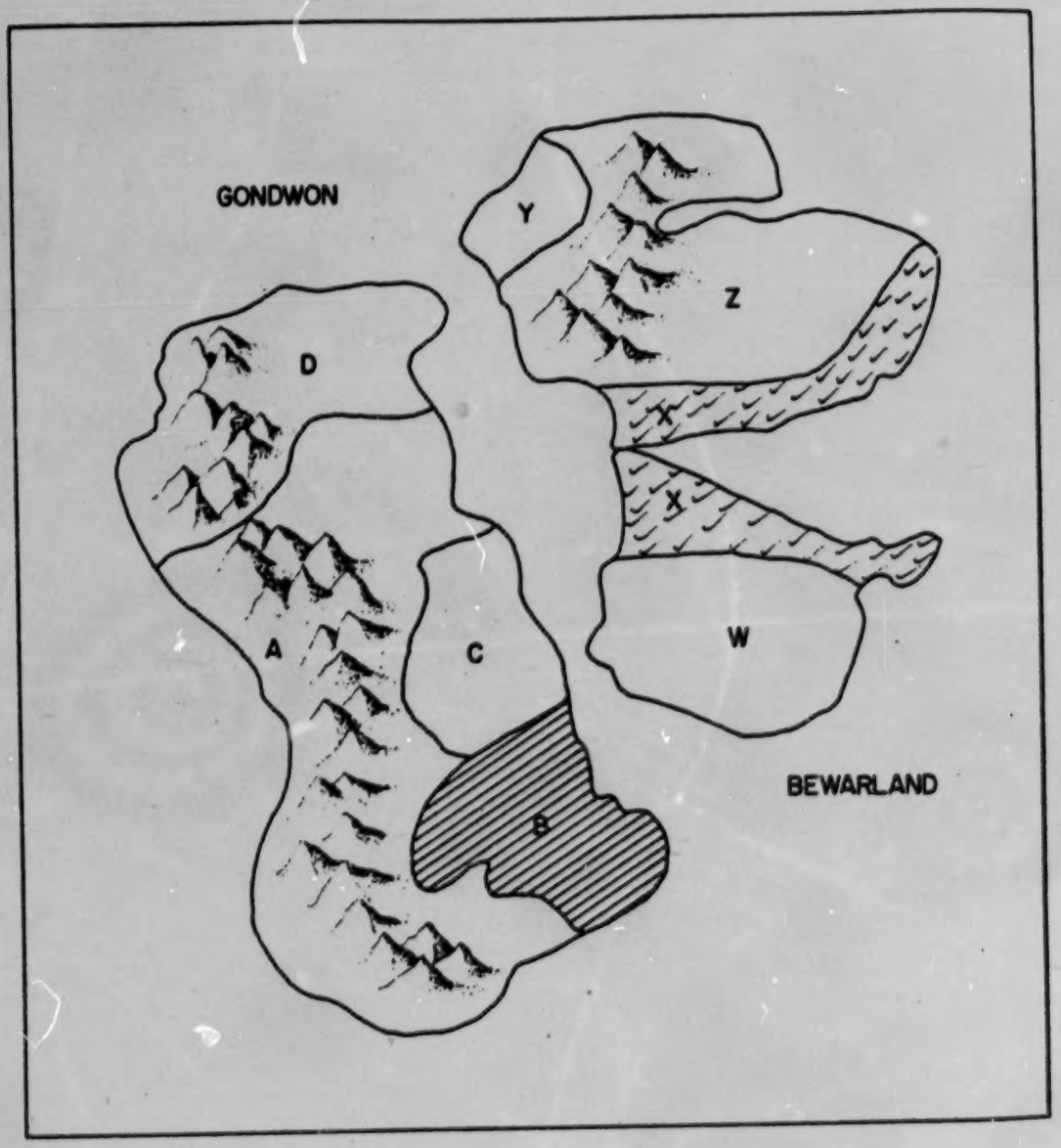


Figure 1



Worksheet 1

Note: Rock ages support the joining of continents if (1) rocks of the same type in corresponding parts of the two continents are about the same age, and (2) there are many, many rock samples of known age to compare. If the rock types are not the same age, then the continents were probably not joined.

Could these two continents once have been one big continent based on the ages of corresponding rock types?

4. To see if the continents fit, cut along the sides that you think fit together. See if the shorelines match.

CAUTION: When cutting out the continent Bewarland, students should not cut through the notch. The activity works better if the continent Bewarland is not cut in half.

Could the continents have fit together at one time?

If you answered "No," or "Don't know," ask your teacher for a hint.

The hint may be reproduced separately and handed out to students upon request, or it may be reproduced on the reverse side of the student worksheet.

HINT!! Everyone knows that when a puzzle is solved, the pieces should fit together perfectly or almost perfectly. Think about this puzzle a minute and then cut completely around each continent. Each continent should be one complete piece. You now have two pieces of paper. What can you do with Bewarland and rock type X in order to make the continents fit together?

What you have just done is similar to one of the methods which scientists use to suggest that continental positions may have been different in the past.

5. Rock units D and W were not analyzed. What are their probable ages?

Rock Unit D _____ Rock Unit W _____

Review Questions

1. What other kinds of evidence might support the idea that two continents were once joined together?

2. Why is it important for scientists to compare corresponding rock types as well as corresponding rock ages when matching rocks on different continents?

Extensions

Read the article by P. M. Hurley in Scientific American, listed in the References, and compare its findings with what you have learned in this activity. (The article was also reprinted in Continents Adrift, 1972, W. H. Freeman and Co.) Do you think that Africa and South America were onced combined into one large continent?

References

Eicher, D. L., Geologic Time, Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1976.

Hurley, P. M., "The Confirmation of Continental Drift." Scientific American, 218(4):63-64, 1968.

Earthquakes and Plate Boundaries

Developed for the
NAGT Crustal Evolution Education Project (CEEP)

by
Paul Lowman, Kathleen Wilkes, and Robert W. Ridky,
published in the Journal of Geological Education,
Vol. 26, p. 69-72, 1978

Introduction

Why do earthquakes occur where they do? What causes earthquakes? Are earthquakes related to any other earth features? The earth's outer shell is believed to be made up of a number of rigid plates, called lithospheric plates, which are from 80 km to 160 km thick. The plates are made up of the two upper rock zones of the earth, the crust and upper portion of the mantle (Figure 1). Some plates include only oceanic crust. Other plates include both oceanic and the lighter continental crust. These plates ride on a zone in the mantle where the rock is almost melted and therefore not rigid. An example to help you picture this would be a block of wood floating in a bowl of honey.

In this investigation you will find that different kinds of both earthquakes and topography are related to different kinds of plate boundaries.

Objectives

Upon completion of this activity, you should be able to:

1. Explain the system used to show the location and depth of earthquakes on the World Seismicity Map.

2. Explain the relationship between earthquakes and plate boundaries.

3. Construct a graph showing the distribution of earthquake depths near a coast, given the location and depth of earthquakes.

4. Describe the distribution of earthquake depths in an area where continental and oceanic plates collide.

5. Describe the relationship between earthquakes and major geographic features in South America. Interpret data to determine the type of plate boundary in a given area.

Materials

World Seismicity Map, compiled by Arthur C. Tarr (1974), U. S. Geological Survey, Branch of Distribution, 1200 S. Eads Street, Arlington, Va. 22202. (Preferably one for each group of students.)

Physical World Map, National Geographic Society, Washington, D.C. 20036. (one or more for the classroom.)

Colored pencils.

Procedure

A great deal of action takes place along boundaries between plates. Large forces build up as one plate moves with respect to another. When the force becomes too great, the rocks snap, causing an earthquake., Different types of movement of one plate against another may occur. Plate boundaries are the sites of much earthquake activity. Both the pattern of earthquake distribution and major topographic features are distinctive of the type of plate boundary and motion. (See Figures 2, 3, 4, and 5.)

It is important that students understand the four types of plate boundaries illustrated in Figures 2-5.

Look at a copy of the World Seismicity Map. PLEASE DO NOT MARK ON THIS MAP, other students must use it. Carefully read the text in the box on the map titled "Explanation" before proceeding.

1. The dots on this map represent earthquakes that occur over _____ years and _____months.

2. Large earthquakes are represented by _____ smaller earthquakes by _____.

The focus of an earthquake is the point within the earth where an earthquake actually occurs. The epicenter of an earthquake is the point on the earth's surface which lies directly above the focus.

3. Which of these two points is represented by the location of the dots on the map showing earthquakes?

4. On the map, what is used to indicate earthquakes of a shallow focus (0-70 km)? _____ intermediate focus (71-300 km)? _____ deep focus (301-700 km)?

Scientists believe that zones of frequent earthquake activity are the result of movements taking place along plate boundaries. Many earth features are associated with plate boundaries. Look at where the earthquakes are located on the World Seismicity Map. Then look at where ocean ridges and trenches are located on the Physical World Map.

5. List at least two major ocean floor features which seem to coincide with the location of major zones of earthquake activity: _____, _____

6. Where do most of the earthquakes occur in South America? _____ List one continental feature which seems to be related to earthquakes. _____

Data about the location and depth of earthquake activity along the west coast of South America near the Tropic of Capricorn are given in Table 1.

7. Plot these data on the graph of worksheet 1, and then answer the questions which follow.

8. Describe the relationship between the location and the depth of focus of earthquakes along the coast of South America as shown by your graph.

9. Compare your graph with the types of plate boundaries shown in Figures 2, 3, 4, and 5. Describe the type of plate boundary which you think is present along the west coast of South America.

Follow the zone of earthquake activity northward from South America past Central America as shown on the World Seismicity Map.

10. Where does the plate boundary appear to change?

11. Offer a possible explanation for this change.

Summary Questions

1. From what you have learned in this investigation, draw a cross section of what you think the profile of the continent and ocean plate boundary might look like along the west coast of South America. (Hint: look at Figures 2, 3, 4, and 5.) On this sketch, show and label the location of the deep Chile-Peru trench and the volcanic mountains of the Andes.

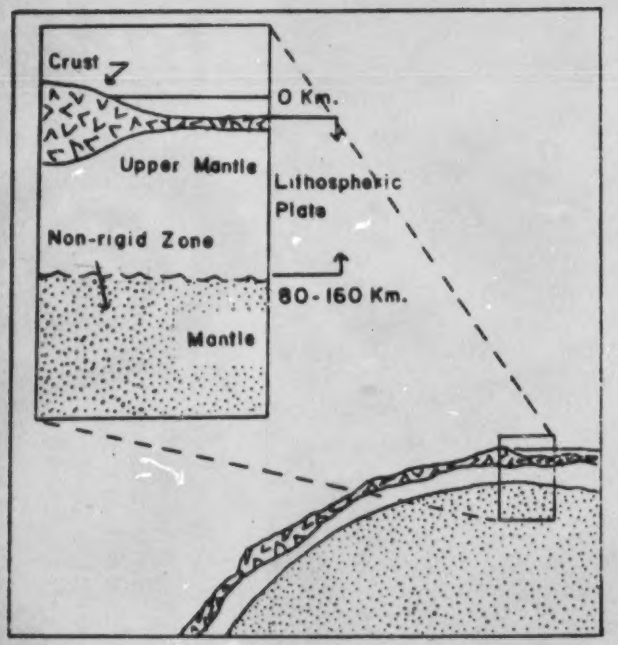


Figure 1 — Diagram showing the rigid lithospheric plates and their relationship to the outer rock zones of the earth. Thickness of zones is not shown to scale.

Table I
Data for use with Worksheet 1

Data Point No.	Dpth (km.)	Distance (km.) and direction from coast
1.	50	0
2.	300	100 East
3.	385	450 East
4.	60	80 East
5.	125	250 East
6.	200	70 East
7.	690	400 East
8.	25	40 West
9.	500	700 East
10.	515	385 East
11.	380	340 East
12.	50	100 East
13.	300	500 East
14.	485	280 East
15.	660	550 East
16.	90	90 West
17.	520	200 East
18.	90	25 West
19.	440	600 East
20.	640	660 East
21.	50	100 West
22.	75	100 West

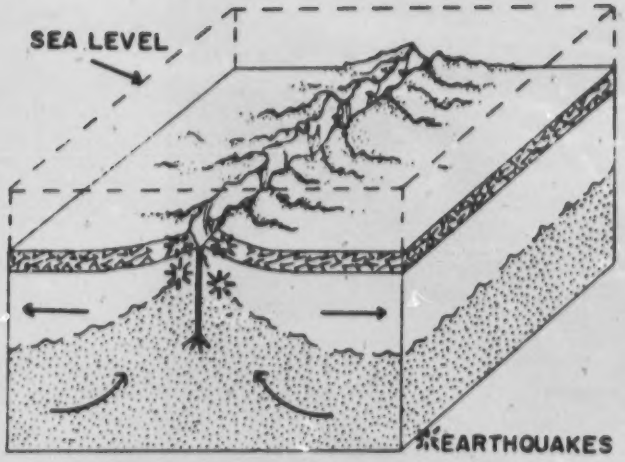


Figure 2 — Plates may move apart from one another.

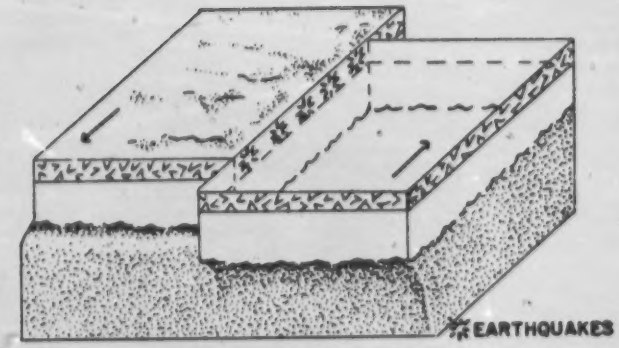


Figure 3 — Plates may move past one another.

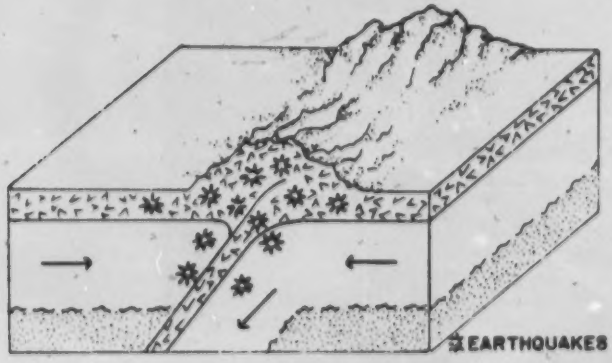


Figure 4 — Plates with continental crust may collide with one another.

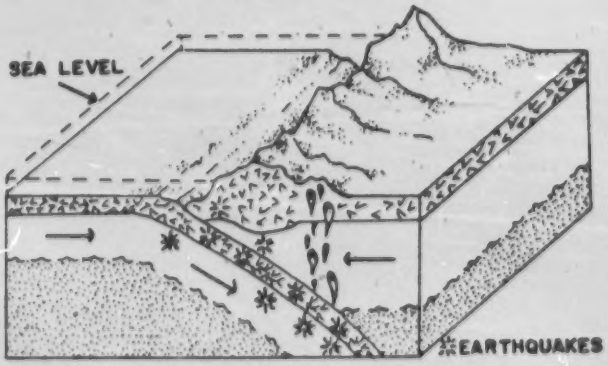
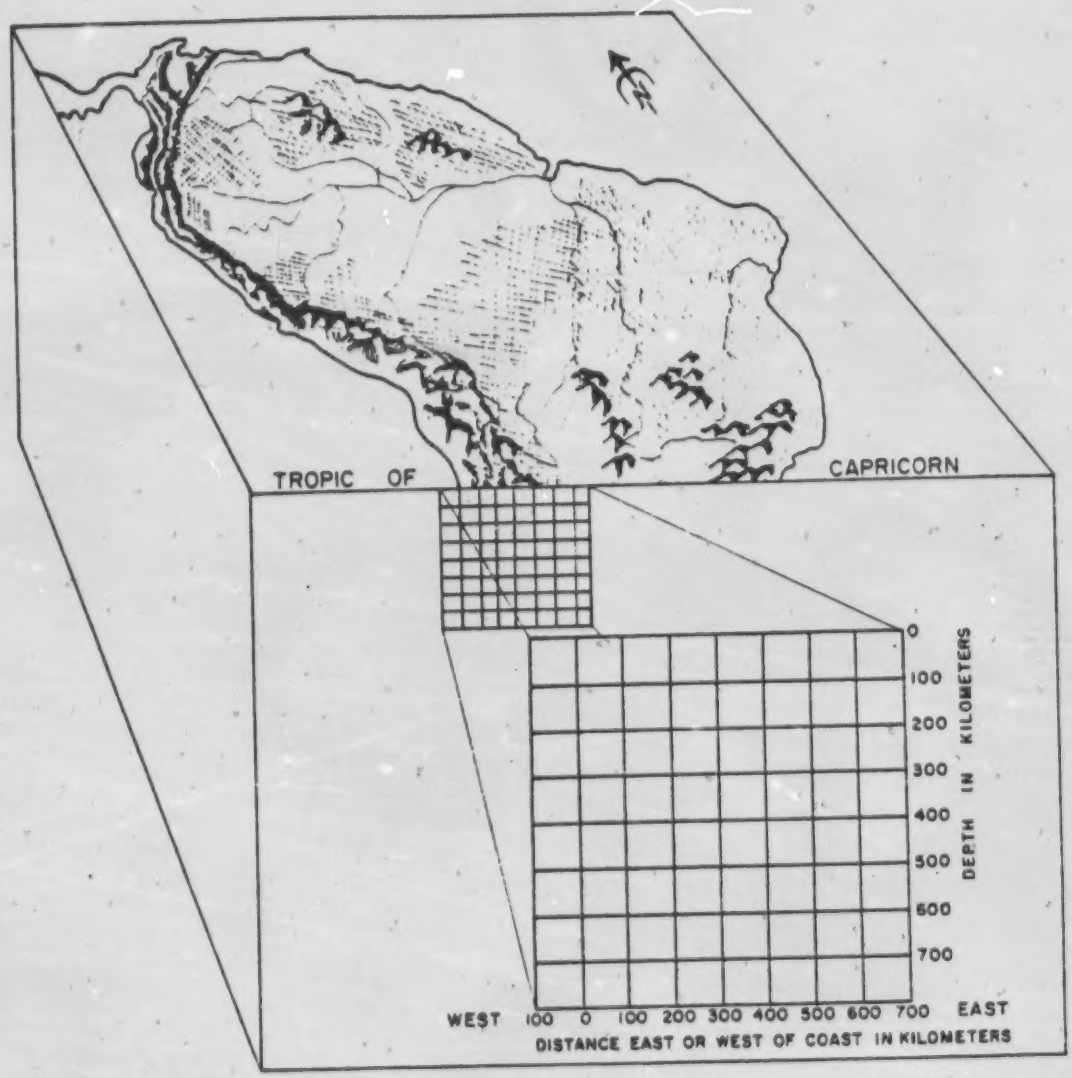


Figure 5 — A plate with oceanic crust may collide with a continental plate.



Worksheet 1 — Map and graph for answering questions 7 through 9

2. In what way is the plate boundary along the coast of California different from the plate boundary along the west coast of South America?

Extensions

1. What type of plate boundary do you think would best account for the type of earthquake activity found in California?

2. Locate three other areas on the earth's surface which would most likely have plate boundaries similar to the one in South America. Explain the reason for your choices.

3. Locate three areas on the earth's surface which appear to have boundaries similar to the kind shown in Figure 2.

4. Locate one area on the earth's surface which appears to have boundaries similar to the kind shown in Figure 4.

References

_____, "The Force That Moves Continents," Science Year, Chicago: Field Enterprises Educational Corporation, p. 177-187, 1973.

Canby, Thomas Y., "California's San Andreas Fault," National Geographic, 143(1): p. 38-53, 1973.

James, David E., "The Evolution of the Andes," Scientific American, 229(2): 61-69, 1973.

Wyllie, Peter J., "The Way the Earth Works," New York: John Wiley and Sons, Inc., 1976.

Which Way Is North?

Developed for the
NAGT Crustal Evolution Education Project (CEEP)

by
Myrl Beck, Robert Christman, Garry Jones,
Maurice Schwartz, Richard Powell, and Larry Johnson,
published in the Journal of Geological Education,
Vol. 25, p. 141-145, 1977

Introduction

You would expect a compass to show the directions toward the magnetic north and south poles. However, while continents can drift or move around, can you depend on the two poles to stay in the same location?

Over long periods of time, the earth's magnetic field changes. Using what you know about paleomagnetism ("fossil" magnetism), together with measurements of magnetism that have been made at sea, it is possible to find out a great deal about movements of the earth's crust. In the investigations that you do here, you will be duplicating one line of evidence that scientists have followed in working out the history of crustal changes.

Objectives

When you have completed this group of activities you should be able to:

1. Identify one of the instruments by which the earth's magnetic field is studied.

2. Tell one way in which the earth's magnetic field changes.

3. Tell why the study of magnetic patterns on the sea floor is useful.

4. Tell where the older and younger parts of the sea floor are located.

5. Figure out in which direction the ocean floors are moving, and how fast.

Part A. Which Way Is North.

Materials

Bar magnet
Compass
10 Boxes each with a bar magnet inside

Procedure

1. Can you and your classmates figure out which way is north? What part of the room is on the north side?

2. Examine the compass your teacher has given you. What colors are at each end of the compass needle?

3. The end of the needle that points to the north is _____ (color).

Even in a set of identical compasses purchased at the same time, the colors of the north-seeking end of the compass will vary, so students should be encouraged to check their compasses each day before proceeding.

For all of these activities, the bar magnets should be labelled so that the north-seeking end of the compass will point to the north end of the magnet. In that way, the bar magnets will be like the earth's magnetic field.

If students question this arrangement, point out that it is merely an artificial means of making the bar magnets resemble the earth's magnetic field, as should become plain later in the investigation.

Put your magnet on the paper so that north is at the top and south is at the bottom.

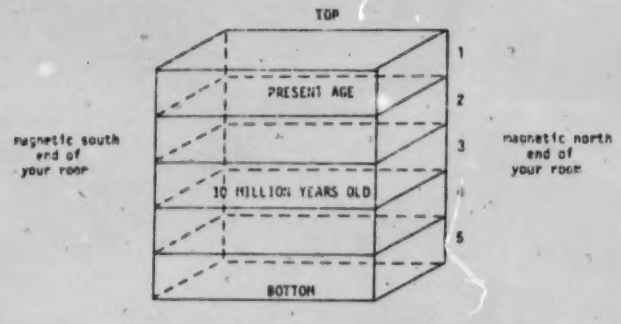
4. Which end of your compass points to the north end of the magnet? _____ (color).

5. Which end of your compass points to the south end of the magnet? _____ (color).

6. Look at the pile of five boxes that has been put out for you to work with. Imagine that each box is a layer of igneous rock, like an old lava flow that cooled and hardened on the surface of the earth a long time ago. The ages of some of the layers are known and are given to you in the diagram below. Since the magnetic field stayed the same in each

layer as it was at the time each layer was formed, you can tell where the magnetic north pole was located by testing these layers of rock with your compass.

Using your compass, find the magnetic north and south pole directions in each layer and label the diagram below to show these directions.



Starting with the magnet in the top box oriented with the end which is labeled North to the right, the bar magnet is oriented in the opposite direction in each successively lower box.

Discuss with the others in your group what you found out about the magnetic north and south directions in these boxes. What you have found is what geologists have found in layered rocks at many places around the world. Now answer these questions.

7. Since these are old lava flows that piled up on the surface on the earth and cooled to form layers of hard rock
   Which is the oldest layer?
   Which is the youngest layer?

8. What did you find out about the magnetic north and south pole direction in each layer?

9. What do you think happened to layers of rocks around the world to cause what you found?

Note that there are actually three valid hypothetical answers possible here: (1) the magnetic poles may have changed places (reversed) each time a layer of rock was deposited; (2) the continent upon which these rocks were deposited may have rotated 180° between the times of deposition of each rock layer; and (3) the magnetic polarity of the rock layers may have reversed itself within the layer. At this point a class discussion of the nature of magnetism and the Earth's field and its variations might be useful. Briefly, possibility (2) is unlikely because of the

rapidity of the total number of rotations which would be required; while possibility (3) is unlikely because of the regularity of alternations in successive layers, the similar polarity of rocks of the same age throughout the world, and the determination that self-reversal, while possible, only occurs if extremely rare combinations of magnetic minerals are present in the rock.

There is a name for this. It is called polarity reversal. When the north magnetic pole is located near the geographic north pole and the south magnetic pole is located near the geographic south pole, we call the earth's magnetic field normal. When the two magnetic poles exchange places, we call the earth's magnetic field reversed.

Part B. Does Polarity Change In The Ocean Floor?

Materials

Compass
boxes

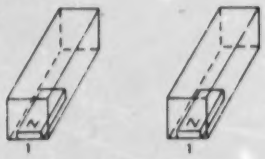
In this part, two identical stacks of boxes, each containing magnets arranged as in Part A, are used. The rise and spreading of new crustal material along midocean ridges can be simulated by placing the stacks on the floor between two desks, and lifting the boxes up to the two desks one pair at a time.

Procedure

You have found out that the record of magnetic north and south pole directions is preserved when layers of rock are formed, even though polarity reversals are taking place. Now, let's look at how these same polarity reversals are preserved in the rocks that are forming in the middle of the mid-ocean ridge.

In this investigation, the boxes in the starting position represent the rocks forming in the middle of a midocean ridge. As they move outward (sideways), and are replaced by newer rocks, they become a part of the ocean floor.

1. Find which end of your compass needle points to the north end of your room. Using the compass, find the magnetic north and south pole directions in each box and label the diagram to show these directions.

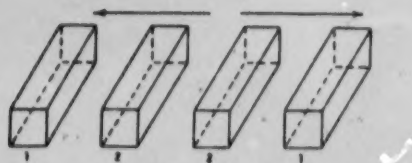


magnetic north end of your room

Do the same thing again, each time your teacher adds another set of boxes.

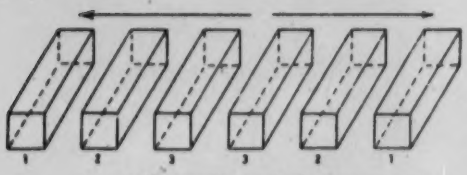
The arrows show which way the boxes are being moved.

2.



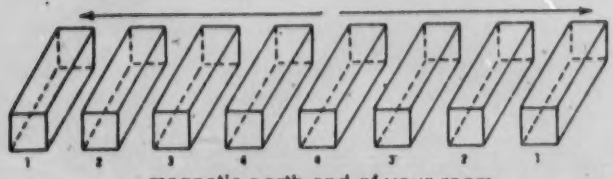
magnetic north end of your room

3.



magnetic north end of your room

4.



magnetic north end of your room

5. Draw a map view of polarity direction preserved in the ocean floor on both sides of a mid-ocean ridge as it would look for the last set of boxes. A map view is what you would see if you were looking down at the earth.

6. What would happen if the ocean floor kept spreading away from a ridge while the earth's magnetic field kept reversing?

Part C. Do Magnetic Reversals Form A Pattern?

Materials

Ruler

Procedure

In this activity, you are going to act like geological

oceanographers on a cruise, collecting magnetic data as you sail in a zig-zag pattern across the north-Atlantic Mid-Ocean Ridge just southwest of Iceland. The information used here is part of the actual data collected by geologists who used an instrument called a magnetometer. The magnetometer was carried aboard a U.S. Navy plane in a magnetic survey of that area. It does not have a compass needle that really reverses. It measures high and low intensities in the magnetic field that show where the normal and reverse areas are located.

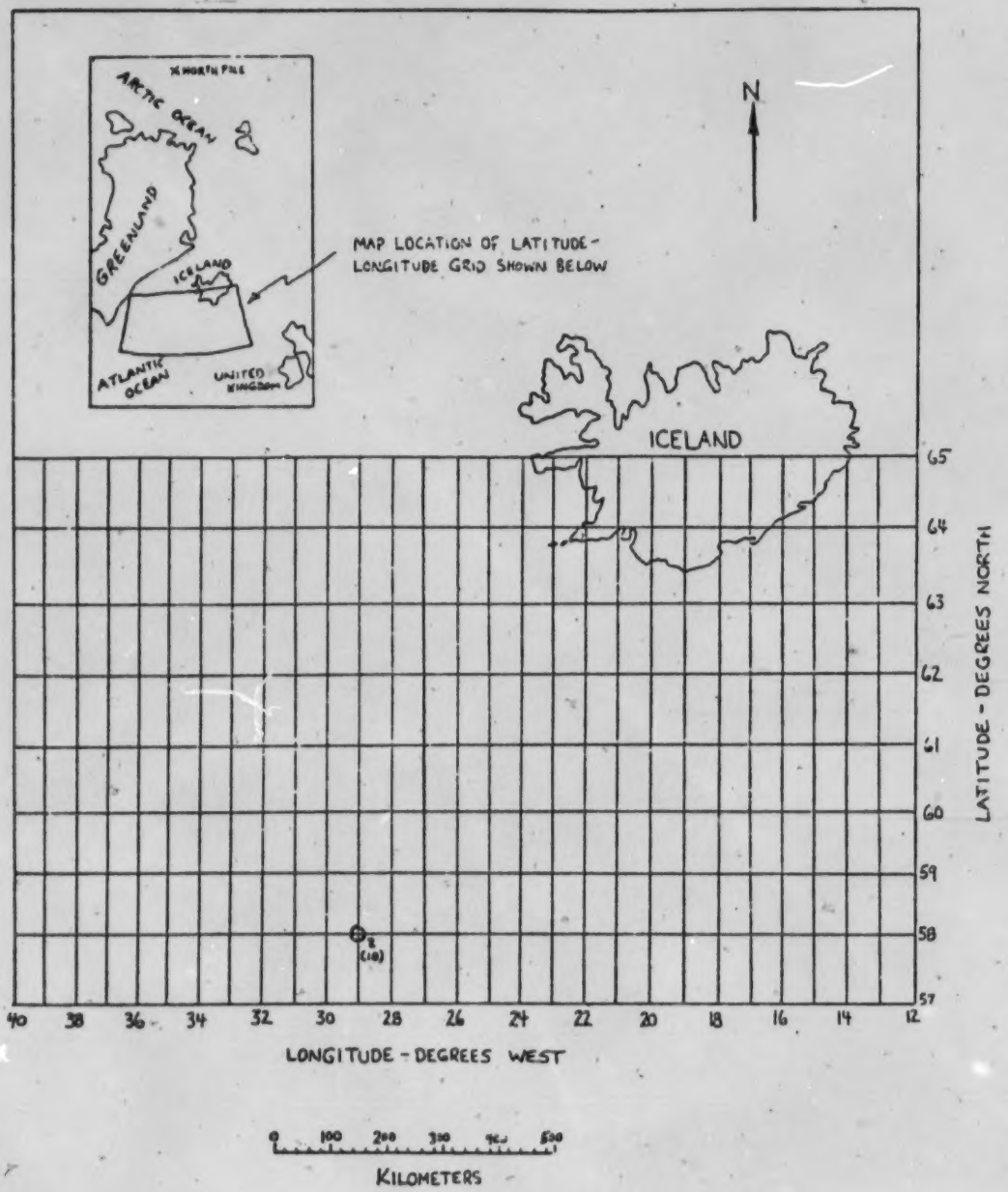
1. On the map that follows, locate each station by latitude and longitude. Station 2 has been plotted as an example.

Station	North Latitude	West Longitude	Magnetic Field Orientation	Symbol	Age*
1	58.0	28.0	Reversed	X	
2	58.0	29.0	Normal	0	10 My
3	58.5	29.5	Reversed	X	
4	58.5	31.0	Normal	0	Present
5	59.0	31.5	Reversed	X	
6	60.0	32.0	Normal	0	10 My
7	61.0	33.0	Reversed	X	
8	60.5	31.0	Normal	0	10 My
9	60.0	30.0	Reversed	X	
10	60.0	29.0	Normal	0	Present
11	59.5	28.5	Reversed	X	
12	59.0	27.5	Normal	0	10 My
13	58.5	26.0	Reversed	X	
14	59.0	25.0	Reversed	X	
15	60.0	24.0	Reversed	X	
16	61.0	24.5	Normal	0	10 My
17	61.0	25.5	Reversed	X	
18	61.5	26.0	Reversed	X	
19	61.5	26.5	Normal	0	Present
20	62.0	27.5	Reversed	X	
21	62.0	28.5	Reversed	X	
22	62.0	29.0	Normal	0	10 My
23	62.5	30.5	Reversed	X	

*My = million years

2. After you have marked all of the normal and reversed symbols and the ages that are given for some locations, draw one straight line with your ruler that will connect all the stations where the rocks are of present age. This will separate the groups of ten-million-year-old rocks. Draw one straight line through each group of ten-million-year-old rocks. Then answer the following questions.

   a. Where do you think the Atlantic mid-ocean ridge is located on your map? What is your reason?
   b. What pattern do you see on your map?
   c. How do you explain this pattern?


NORTH POLE
ARCTIC OCEAN
GREENLAND
ICELAND
ATLANTIC OCEAN
UNITED KINGDOM
MAP LOCATION OF LATITUDE-LONGITUDE GRID SHOWN BELOW
N
ICELAND
65
64
63
62
61
60
59
58
57
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
LATITUDE - DEGREES NORTH
LONGITUDE - DEGREES WEST
0
100
200
300
500
KILOMETERS

3. If the ocean floor on each side of the ridge is moving, draw arrows on your map to show in what direction the different parts are moving. How do you know this?

4. If a car traveled 100 miles in two hours, how fast was it going (miles per hour)? How can you find out how fast the ocean floor is moving on each side of the ridge?

5. Find the rate (in centimeters per year) at which the ocean floor is moving in the area of this investigation. (Remember that one kilometer equals 1000 meters, and one meter equals 100 centimeters. Therefore, to convert kilometers to centimeters, you must add five zeros to the number of kilometers.)

Summary Questions

1. You have looked at just a small portion of the approximately 64,000 km of mid-ocean ridges that run through the world's ocean basins. Do you think that what you found southwest of Iceland would be found alongside the rest of the ridges?

2. How far out from the ridge area that you studied here would you expect to find the magnetic reversal patterns on the ocean floor?

3. As you go away from a mid-ocean ridge, how do you think the age of the bottom-most sediment on the ocean floor would change?

4. Lay two pieces of paper side by side, overlapping just a little bit. Put your finger at the top (where the two overlap) and spread the papers apart, slowly, at the bottom. Now answer this question. The Atlantic Mid-Ocean Ridge runs from near the Arctic Circle at Iceland down to and across the equator. How would you expect the spreading rate near the equator (what you calculated in this activity) to compare with the spreading rate near Iceland?

Extensions

You found a spreading rate for the ocean floor just southwest of Iceland. Now measure the distance, in kilometers, from Labrador to Great Britain on a map. Can you figure out how long ago North America and Europe would have had to have separated in order to get that far apart by now? Compare the number of years that you get for an answer with a geologic time scale to see what geologic period your answer would fall in.

References

Alexander, T., "A Revolution Called Plate Tectonics has Given us a Whole New Earth." Smithsonian, 5(10). 30-40, 1975. (First of a two-part article.)

_____ "Plate Tectonics has a Lot to Tell us About the Present and Future Earth." Smithsonian, 5(11):38-47, 1975.

Heirtzler, J. R., "Sea-Floor Spreading." Scientific American, 218(6):60-70, 1968. (also in Continents Adrift and Continents Aground, H. W. Freeman and Company, p. 76-86, 1976.)

Sea-Floor Spreading and Transform Faults

Developed for the
NAGT Crustal Evolution Education Project (CEEP)

by
Ronald E. Armstrong, Paul J. Fox, and Warren E. Yasso
published in the Journal of Geological Education,
Vol. 26, p. 19-21, 1978

Introduction

Materials needed include wall maps of world seismicity and of sea-floor topography of the Atlantic Ocean (preferably one of each for every 10-12 students) and a cardboard-and-paper sea-floor spreading model (one for each pair of students). Any maps showing Atlantic Ocean sea floor topography and world seismicity are satisfactory. One example of each is:

Ocean Floor Relief Map of the Atlantic (1973), Nr. 02562, National Geographic Society, P.O. Box 2806, Washington, D.C. 20013. Cost $2.

World Seismicity Map, compiled by Arthur C. Tarr (1974), U.S. Geological Survey, Branch of Distribution, 1200 S. Eads Street, Arlington, Va. 22202. Cost $1.50.

The sea-floor spreading device may be constructed by the teacher ahead of time, or it may be constructed by students as a group activity. It consists of two parts -- a re-usable cardboard base and an expendable paper overlay (see Figures A, B and 3).

The base, approximately 9 x 12 inches in size, can be cut from any stiff cardboard, such as a corrugated cardboard carton. Two slits, approximately 4-1/4 inches in length and 1/8-inch wide, are cut into the base, as shown in Figure A.

The overlay is made from an 8-1/2 x 11-inch sheet of paper, labeled as shown in Figure B, and reproduced in quantity. Cut the paper down the center and then tape the end together with two short strips of masking tape as shown.

To prepare the model for use, place the overlay lengthwise on the cardboard base. Hold several 3 x 5 index cards together and push the paper overlay into the two slots until each pair of lines labeled MAR (for Mid-Atlantic Ridge) meets at the slot. The model is then ready for student use.

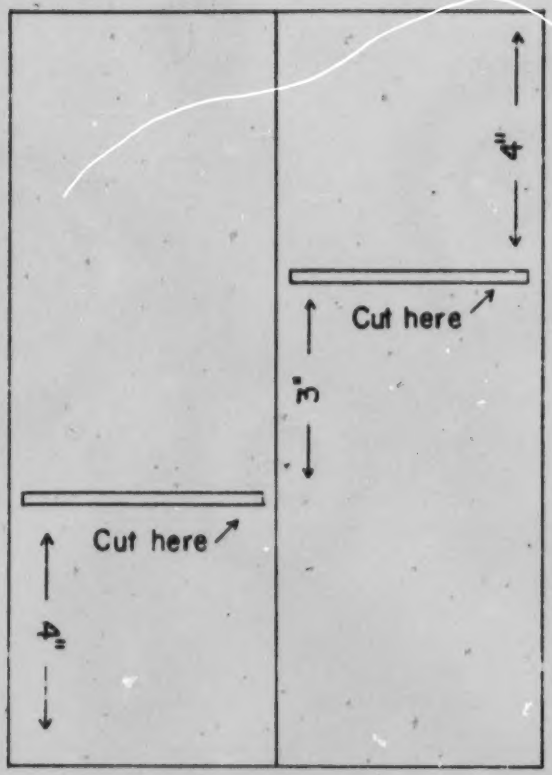


Figure A — Cardboard base of sea-floor spreading module.

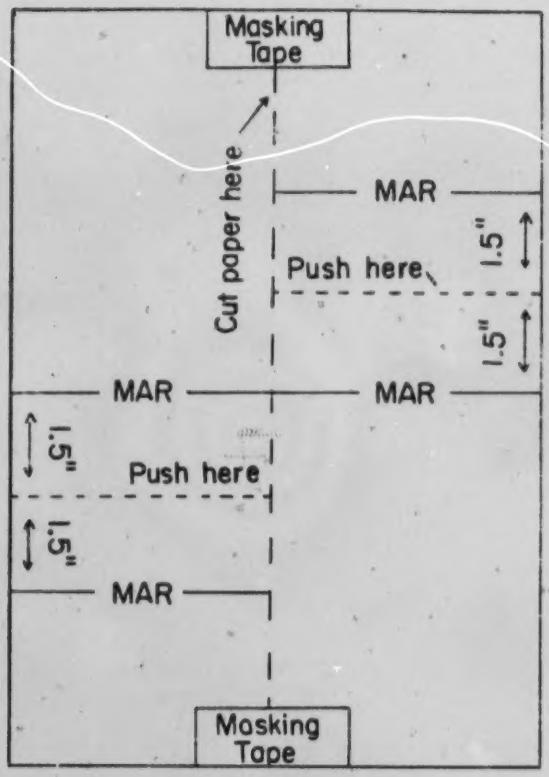


Figure B — Teacher instructions for preparing 8½ × 11-inch paper overlay for sea-floor spreading device. Overlay should be labeled as shown in boldface type.

This module should take only one 45-minute class period if the model device is prepared ahead of time.

When scientists first mapped the mid-ocean ridge in the Atlantic Ocean, it seemed like a fairly regular submarine mountain range. But, in 1953, Marie Tharp discovered that the Mid-Atlantic Ridge is split down the middle. Further mapping showed an even more curious thing - the ridge isn't a continuous line of mountains! At many places the ridge is offset. From the end of one section, you have to travel east or west to find the next section.

Scientists today have come to recognize mid-ocean ridges as places where a process called sea-floor spreading is taking place. In this process, new oceanic floor is created by the cooling and solidification of hot molten rock material. This hot material rises along the ridge at the same rate as the two sides of the ridge are moving apart (Figure 1).

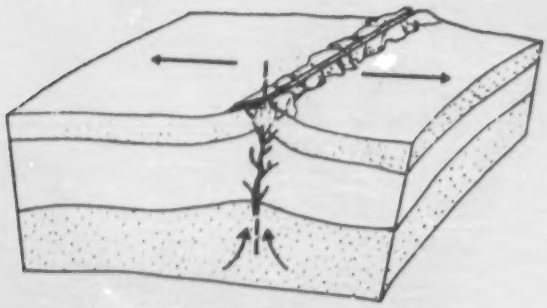


Figure 1 — Sea-floor spreading. New oceanic floor is created as the two sides of the ridge move apart.

Figure 2 shows how two sections of ridge are separated from each other. The line along which they are separated is called a fracture zone. This is a zone where blocks of rock have moved past each other. This movement causes earthquakes. Earthquakes in and near the ridge areas show that the blocks of rock are still moving today. Exactly how is the movement taking place? What does this movement tell us about plates?

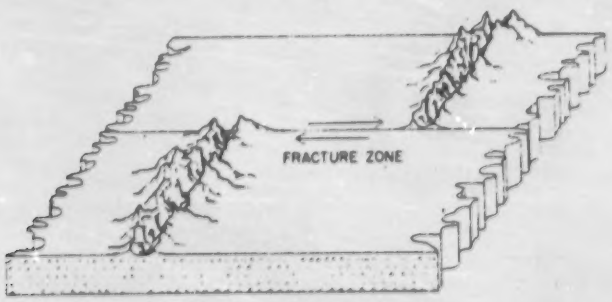


Figure 2 — A mid-ocean ridge offset by a fracture zone. Arrows show the apparent direction of relative movement along the fracture zone.

Objectives

When you have completed this investigation, you should be able to:

1. Describe the direction of movement of the sea floor on either side of a fracture zone.

2. Describe the relation between sea-floor spreading and fault motion along fracture zones.

3. Explain why earthquakes usually happen along only a part of a fracture zone, and give the correct name for this zone.

Prior to doing this module, students should have already become familiar with the basic types of faults (normal, reverse, and strike-slip). Ideally, they should have manipulated wooden-block models of these faults to learn how rock bodies move relative to each other in each type of faulting.

Students should also have a general knowledge about the topography of the sea floor, including mid-ocean ridges and fracture zones.

Materials

Map of the Atlantic Ocean Floor
World Seismicity Map
Sea-floor spreading device

Procedure

1. Look at the map of the Atlantic Ocean Floor and find the Romanche Fracture Zone. It is at the equator between eastern South America and western Africa.
   Make a sketch to show the entire length of the Romanche Fracture Zone and the sections of Mid-Atlantic Ridge just above and below it.

2. Look at the World Seismicity Map and find where the Romanche Fracture Zone is along the equator. Study the earthquake pattern along the fracture zone.

   (a) On your sketch of the Romanche Fracture Zone, place dots where earthquakes have occurred.

   (b) Write a sentence telling where the earthquake pattern occurs relative to the sections of Mid-Atlantic Ridge just above and below the fracture zone.

3. Study the sea-floor spreading device at your lab station. The central long slit running lengthwise along the paper worksheet represents a fracture zone. The sections of Mid-Atlantic Ridge (labeled MAR) are above and below the fracture zone. Label the central slit line, "fracture zone." Write a sentence that describes how the sea-floor spreading device should be oriented so that it shows the same arrangement of fracture zone and Mid-Atlantic Ridge sections as the diagram which you drew of the Romanche Fracture Zone.

4. (a) On your sea-floor spreading device draw a short line across the fracture zone to the left of the lower section of the Mid-Atlantic Ridge. Label both ends of the line "A" (see Figure 3).

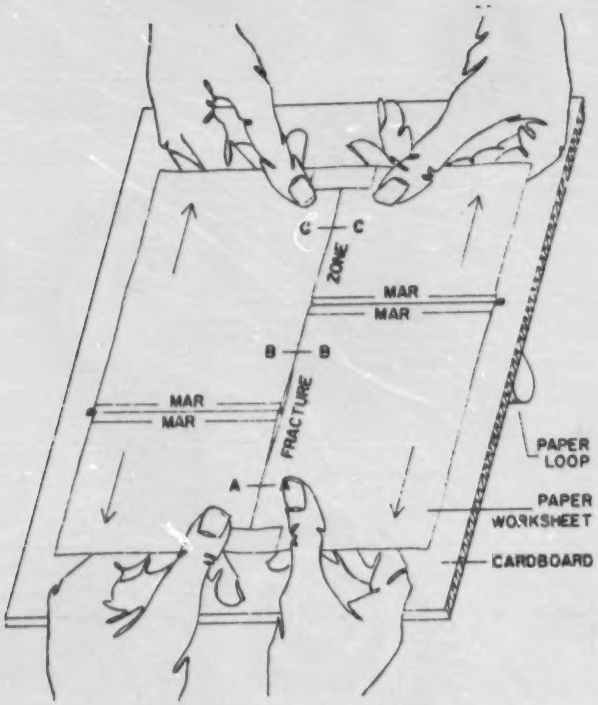


Figure 3 — Sea-floor spreading device, labeled as indicated in the instructions. Note the manner in which the device is to be operated.

(b) Make a similar line between the section of Mid-Atlantic Ridge. Label both ends of the line "B."

(c) Make a similar line to the right of the upper section of Mid-Atlantic Ridge. Label both ends of the line "C."

5. Work with a partner who will face you on the other side of your lab table. Both of you should grasp the worksheet as shown in Figure 3. Now, both you and your partner should pull your ends of the worksheet slowly toward yourselves. CAUTION - stop pulling before the paper loops come out of the cardboard! As you both pull on the worksheet, look to see which parts of the fracture zone are moving past each other and which are not. If necessary, pull the paper loops back down through the cardboard and repeat the procedure.

(a) Make a sketch to show how each set of labeled lines (AA, BB, and CC) are moving.

(b) Based on your sketch, write a sentence that describes the portion of the paper which is moving in opposite

directions on either side of the fracture zone. This portion of a fracture zone is called a transform fault.

(c) The paper worksheet represents the Romanche Fracture Zone and sections of the Mid-Atlantic Ridge. Write a sentence that describes what part of the real Romanche Fracture Zone is related to the earthquake pattern on the fracture zone.

(d) Write a sentence that tells how the transform fault part of the Romanche Fracture Zone is related to the earthquake pattern on the fracture zone.

Summary Questions

1. Decribe what happens to a mid-ocean ridge that is cut by a fracture zone.

2. What is a fracture zone?

3. Which part of a fracture zone is a transform fault?

4. Describe the direction in which the sea floor spreads.

5. Did sea-floor spreading change the position of the Mid-Atlantic Ridge sections in your model?

6. Why do earthquakes occur only on the transform fault part of a fracture zone?

7. Define the term "transform fault."

Extensions

Study physiographic maps of the Arctic, Pacific, and Indian Oceans, such as those found in the National Geographic series on the ocean floor. Describe the location (latitude, longitude) of major shifts in the mid-ocean ridge where it crosses a fracture zone. Do these locations correspond with earthquakes on the transform faults?

Students will find that earthquake zones do correspond with transform fault locations throughout the world. They will also note that the direction of offset of ridges by transform faults is in some cases just the opposite of the offset in the vicinity of the Romanche Fracture Zone which was examined in this investigation. In every case, however, the relative motion of the ocean floor on either side of the transform fault is just the opposite of that suggested by the ridge offset.

Have students turn the worksheet upside down and set it into the cardboard which has also been turned upside down. In this way they will be simulating a part of the mid-ocean ridge where the segment of ridge opposite to the viewer is offset to the right relative to the segment nearest the viewer. Students would then repeat steps 4 and 5 of the procedure and compare results with those obtained from the original configuration of ridge segments.

References

Alexander, Tom. "A Revolution Called Plate Tectonics has Given us a Whole New Earth." Smithsonian, 5(10):30-40, 1975.

Alexander, Tom. "Plate Tectonics has a Lot to Tell us About the Present and Future Earth." Smithsonian, 5(11):38-47, 1975.

Matthews, S. W., "This Changing Earth." National Geographic, 143:137, 1973.

How Fast Is The Ocean Floor Moving?

Developed for the
NAGT Crustal Evolution Education Project (CEEP)

by
Arie Korporaal, Craig Huff, Gaylen Carlson, and Tracy Vallier,
published in the Journal of Geological Education,
Vol. 26, p. 104-107, 1978

Introduction

Many earth scientists believe that the continents of Africa and South America were once joined together. What is the evidence for this belief? If it is true, how long has it taken for these two continents to break apart and move to where they are now? Are other continents moving?

One way to answer these questions is to study samples of sediment (loose rock, mineral debris, plant fragments and animal shells which have settled out of water) taken from the ocean floor. In these activities you will use sediment data as scientists do to determine how fast the ocean floor is moving.

The deep sea sediments were obtained by the Glomar Challenger. The Glomar Challenger is a specially designed drilling ship that can obtain samples of sediment and rock from the floor of deep ocean basins. It recovers both sediment and rock cores. A core is a cylinder of sediment or rock obtained by using a hollow drill. In many cases, scientists must drill through hundreds of meters of sediment before reaching the solid igneous rock of the ocean floor. The igneous rock forms by cooling and hardening of molten rock material. It represents the "floor" upon which the sediments settle.

Objective

When you are finished with these activities, you should be able to:

1. Make and interpret graphs which show the relationship between sediment thickness and distance to a mid-ocean ridge.

2. Make and interpret graphs which show the relationships between the age of deep sea sediments and the distance to a mid-ocean ridge.

3. Form hypotheses about sea-floor movement based on data from sediment cores.

4. Calculate the rate of movement of the ocean floor, given data on sediment thicknesses, ages of sediment, and locations of the drill sites.

Part A. What Do Deep-Sea Sediments Tell Us?

Materials

One or two copies per class of the Map of the Pacific Ocean Floor which can be purchased from the National Geographic Society, Washington, D.C. 20036.

A Metric Ruler for each student group.

Procedure

The data you will be using in this activity are based on measurements from sediment cores. The Glomar Challenger drilled these sediment cores near the East Pacific Rise. The East Pacific Rise is part of a 64,000 km-long mid-ocean ridge system. Mid-ocean ridges are thought to be places where the process of sea-floor spreading, which results in break-up and separation of continents, takes place. Below is a map showing where the cores were drilled.

Table 1 contains data about position and thickness of deep sea sediments lying on top of the igneous rock of the ocean floor and the age of the sediments immediately above the igneous rock (bottom sediment).

1. Using the sediment thickness data from Table 1, complete the top graph on Worksheet 1. Plot distance to the East Pacific Rise along the horizontal axis. Plot sediment thickness along the vertical axis. Do not plot data from Site 84 at this time. This site is unusual, and you will plot it later.

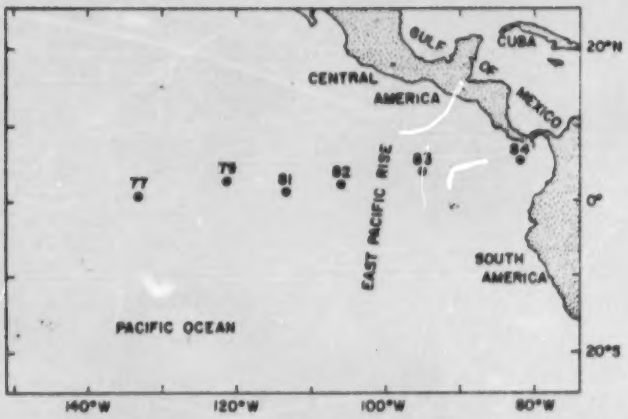


Figure 1 — Glomar Challenger Deep Sea Cores. Leg 9. December 1969 to January 1970. (Modified from Hays, J. D., and others, 1970, p. 12, with permission.)

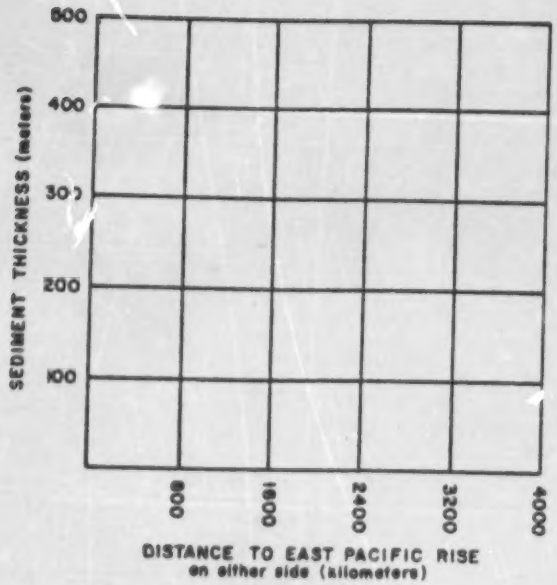
Drill Site Number and Location	Distance to Middle of East Pacific Rise	Sediment Thickness Above Igneous Rock	Bottom Sediment Age (millions of years old)
77 (West of East Pacific Rise)	3,359 km	481 m	36
79 "	2,086 km	414 m	21.5
81 "	1,280 km	409 m	14.5
82 "	549 km	214 m	9.5
Approximate Ridge Axis	0 km	none recovered	0
83 (East of East Pacific Rise)	797 km	241 m	10.5
84 "	2,000 km	254 m	8.5

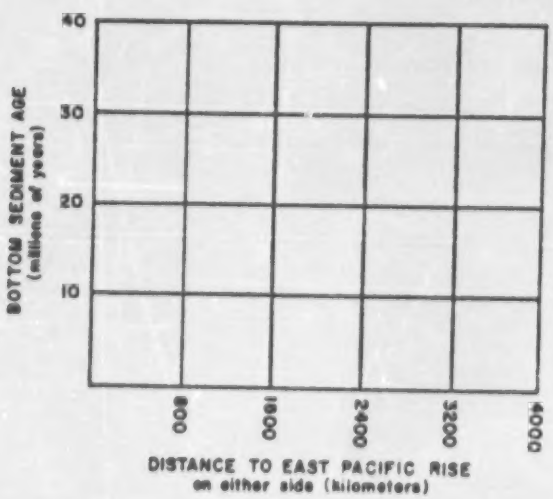
Table 1 — Glomar Challenger Deep Sea Cores. Leg 9. December 1969 to January 1970. (Modified from Hays, J. D., and others. 1970, p. 12).

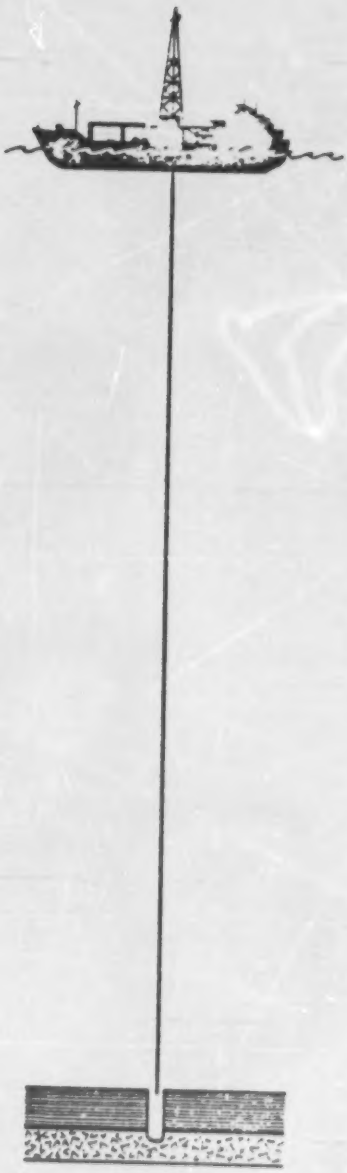
Students may need help completing the graphs. Remind them not to plot Site 84 until after completing both graphs. The graph of sediment thickness data is not a straight line. Show students how to adjust a "best fit" line.

2. In the center of Worksheet 1 is a profile on the top of the igneous rock of the ocean floor on either side of the East Pacific Rise. Sketch in how you think sediment thickness changes in both directions away from the middle of the East Pacific Rise.

WORKSHEET 1
(PART A)







3. Explain what your graph and sketch mean.

4. Does your graph of distance versus sediment thickness lend support to the sea-floor spreading theory? Why or why not?

5. Plot the age of the rocks at the bottom of the sediments in the lower graph of Worksheet 1. For each drilling site number, plot the distance to the ridge center along the horizontal axis. Plot bottom sediment age along the vertical axis. Do not plot the data from Site 84 at this time. This site is unusual, and you will plot it later.

The graph of bottom sediment age should be virtually a straight line. The "bottom age" data is the age of the bottom-most sediments lying in contact with the basaltic ocean crust. The age, therefore, represents the inferred age of the sea floor (or crust) at a particular site.

6. Explain what your graph shows about the relation of bottom sediment age to distance to the middle of the East Pacific Rise.

7. Does your graph in question 5 support the theory of sea-floor spreading?

8. Now plot the data from Site 84 on both of your graphs (Questions 1 and 5).

9. Let's be sure you understand why Site 84 is unusual. From Table 1 you can see that Site 84 is located almost the same distance from the middle of the East Pacific Rise as Site 79. But the Site 84 points you plotted on your graphs are not near the points for site 79. From the first graph you can see the sediment at Site 84 is not as thick as expected. In the second graph, you can see the age of the sediments is less than expected. Something really is unusual at Site 84 on the core map. Determine its location on the National Geographic map of the Pacific Ocean Floor (your teacher has a copy). Sketch on the core map any feature of the National Geographic map which might help explain the unusual data from drill Site 84.

The fact that the data appear anomaloue (do not fit the pattern) suggests that the sediments at Site 84 may be influenced by their proximity to the Cocos Ridge. If the Cocos Ridge is a spreading center, the sediments do "fit" and further support the theory. Students should sketch in the approximate position of the Cocos Ridge on the core map.

10. Assume that each drill core costs about $1,000,000 to complete. You have just received $4,000,000 to drill new

cores. You are in charge of the drilling ship. You need more information to explain the unusual data at Site 84. Where would you locate new drill sites? Show your drill sites on the core map and explain the information you hope to gain at each new site.

Part B. How Can Sediment Data Be Used To Determine The Rate Of Movement Of The Ocean Floor?

Materials

Metric ruler

Some students may need help in converting kilometers to centimeters (100 cm/m x1000 m/km=100,000 cm/km or 1 x 10(5) cm/km).

Procedure

Suppose a car starts from a given point and is driven for 10 hours in a straight line. At the end of 10 hours it is found to have traveled 50 km. How fast did the car move? You know that rate equals distance traveled divided by time, or

$$\text{Rate} = \frac{\text{Distance}}{\text{Time}}$$

therefore,

$$\text{Rate} = \frac{50 \text{ km}}{10 \text{ hours}} = 5 \text{ km per hour}$$

You can use this same formula as you investigate ocean-floor movement.

1. Using Table 1 you can see that the bottom sediment at Site 77 is 36 million years old. What is the rate at which the ocean floor moved to carry the bottom sediments 3,359 km from the middle of the East Pacific Rise? Write your answer in centimeters per year. (You can ask your teacher to help you if you have difficulty changing kilometers to centimeters.)

2. Imagine that the Glomar Challenger drilled a core 7,100 km west of the East Pacific Rise. How old would you expect those bottom sediments to be? (HINT: You will have to change the formula to read time equals distance moved divided by the rate.)

3. Examine Table 2 below. You can see that the average movement rate for the first 10 million years was 6.5 cm per year. For the next 10 million years the rate was 11.5 cm per year. What do the different movement rates indicate? Has the Pacific Ocean floor near the East Pacific Rise moved at the same rate all through its history?

4. Measure your height in centimeters. How long would it take the East Pacific Rise to move the same distance as you are tall?

Time interval	Average movement rate
0-10 million years	6.5 cm/yr.
10-20 million years	11.5 cm/yr.
20-37 million years	9.4 cm/yr.

Table 2 — Rates of sea-floor movement west of the East Pacific Rise.

Summary Questions

1. Scientists think that the process of sea-floor spreading occurs in the Atlantic Ocean just as it does in the Pacific. Core samples have been drilled in the Atlantic Ocean floor. Do you think bottom sediments drilled near the North American continent are older than the sediments drilled near the Mid-Atlantic Ridge? Explain your answer.

2. Could you figure out how fast the East Pacific Rise is moving if you didn't know the age of the bottom sediments? Why or why not?

Extensions

Pretend you are a scientist who does not believe the theory of sea-floor spreading is correct. Make alternate hypotheses to explain the data. How would you explain the sediment thickness data?

Put your arguments in written form and "publish" a scientific article so that your classmates can read it. Persuade other students to propose different hypotheses and write articles explaining their theories.

This can be the most exciting portion of the lab. Encourage students to offer hypotheses that explain the data.

You can improve their writing skills by asking them to write

an article as if it were to be published in a scientific journal. Have them circulate it to other members of the class. The writing of one's ideas and explaining them to colleagues often enhances understanding of the original concept in question.

Students should be encouraged to offer their own hypotheses to explain the data presented in this module. It may be difficult to do, but it can be and has been done most notably by a Soviet geologist, Belossov, and the American petroleum geologist, Meyerhoff. Syntheses of their arguments can be found in Sullivan's book listed in the references.

A point might well be made here. Any single piece of data presented in this module by itself does not necessarily "prove" the theory of sea-floor spreading. It is the sum of all observable evidence, including much not presented here, that makes such a strong case in favor of the theory. It should be pointed out, however, that one of the strongest single pieces of data supporting the theory of sea-floor spreading is the observed magnetic anomalies coupled with age dating of the corresponding rocks.

References

Calder, N. "The Restless Earth: a Report on the New Geology." New York: Viking Press, 1972.

Davis, R. A. "Principles of Oceanography." Reading, Mass.: Addison-Wesley Co., p. 411-433, 1977.

Hays, J. D., et al. "Deep Sea Drilling Project: Leg 9" Geotimes, 15(4):11-13, April, 1970.

Matthews, S. W. "The Changing Earth." National Geographic, 143, (1):1-37, January 1973.

Sullivan, W. "Continents in Motion - the New Earth Debate." San Francisco McGraw-Hill Book Company, 1974.

Wyllie, P. J. "The Way the Earth Works: an Introduction to the New Global Geology and its Revolutionary Development." New York: John Wiley & Sons, Inc., 1976.

Fossils As Clues
To Ancient Continents

Developed for the
NAGT Crustal Evolution Education Project (CEEP)

by
Keith M. Schlarb, David H. Elliot, Victor J. Mayer,
James W. Collinson, and R. Jon McQuillan,
published in the Journal of Geological Education,
Vol. 26, p. 155-199, 1978

Introduction

In the early 1900's a famous English explorer, Captain Robert Scott, made a surprising discovery when exploring the cold and forbidding continent of Antarctica. Captain Scott describes the discovery in his diary in this entry for February 8, 1912:

> We found ourselves under perpendicular cliffs of Beacon sandstone, weathering rapidly and carrying veritable coal seams. From the last Wilson, with his sharp eyes, has picked several plant impressions, the best a piece of coal with beautifully traced leaves in layers, also some excellently preserved impressions of thick stems, showing cellular structure...

This was written upon Scott's return from the South Pole. The coal seams and plant fossils had been found at the base of Mount Bowers at the head of the Beardmore Glacier.

Geologists generally suppose that coal is formed in temperate or tropical regions. How could it have formed in Antarctica which is now almost entirely covered by glacial ice?

Objectives

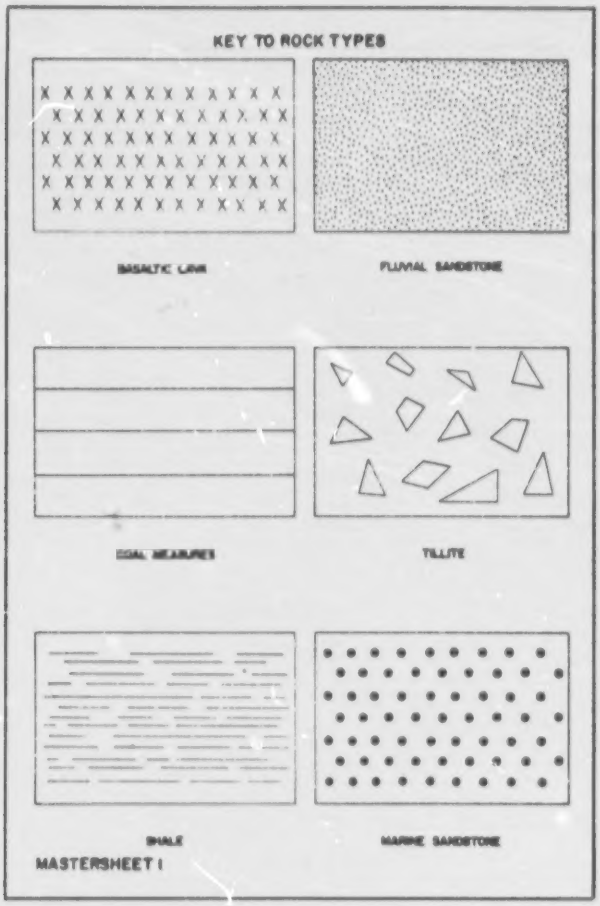
Upon completion of this activity, you should be able to:

1. Tell how rocks indicate the environment in which they were formed.
2. Use superposition to determine the relative ages of rock units.
3. Use fossils to correlate rock units.
4. Describe evidence which supports the theory that certain continents were once joined together.

Part A. What Do Rocks Tell About Past Environments?

Materials

One set each of six rock samples and six rock-type cards per student group (1-4). The rocks needed are basaltic lava, marine sandstone, fluvial sandstone, shale, tillite and coal. All may be obtained from most earth science supply houses. However, many of the rock types may be available locally, or already on hand. Specimens need only approximately match the characteristics listed in the module. In place of tillite, a conglomerate with some angular grains may be used. The teacher should reproduce the rock-type cards ahead of time using the key provided, cut out the symbols and paste them on individual 3 x 5 cards.



Procedure

A geologist is a scientist who studies rocks and what they tell about the history of the earth. Your teacher will provide you with six rocks that have been identified and described by geologists.

1. Identify each of your rocks. You will have one of each of the following:

   Basaltic lava was formed from molten rock that erupted from volcanoes or from long cracks in the earth's crust. It is dark and so fine-grained that you will not be able to see individual grains. It may have round holes formed by gases released from the molten rock and then trapped in the lava as it hardened.

   Marine sandstone was formed from sediments deposited in a sea or ocean. Usually it will contain only quartz grains. Individual grains will all be of about the same size. Fossils will be of animals that lived in salt water.

   Fluvial sandstone was formed from sediments deposited in the bed of a stream. It may have minerals other that quartz, and the mineral grains will be various sizes. If there are any fossils, they will be of land plants or animals.

   Shale is a very fine-grained rock formed from clay or mud. It will show some layering.

   Tillite is a rock formed from sediment deposited by a glacier. These rocks may have a wide variety of grain sizes and minerals. Many of the grains will be somewhat angular.

   Coal is formed from the remains of trees and other plants that grew in swamps. Coal will be black and may have fossilized leaves and plant stems.

2. After you have identified each of the six rocks, place them on the card which has the correct symbol representing the rock. HAVE YOUR TEACHER CHECK YOUR ROCK IDENTIFIICATION BEFORE YOU CONTINUE WITH THE ACTIVITY. Notice that each of the symbols on the cards is used in the Rock Columns Chart provided by your teacher. Remember what each symbol means and also the kinds of conditions under which each rock type was deposited.

3. Apply the principle of superposition to the South Africa rock column of the Rock Columns Chart (Worksheet 2). Which rock layer is the oldest? Which layer is the youngest?

4. What was the environment of Antarctica like when the marine sandstone was being deposited? What was the environment like when the coal was being deposited?

5. Does the present environment in Antarctica differ from either of those you described in question 4 above? If so, how does it differ? Could coal be forming in Antarctica today?

6. Locate India on the map. What type of climate do you think India has today?

7. Now examine the rock column for India. Could rocks similar to those represented by the rock columns be forming in India today? Which ones? Could tillite be forming today?

The one rock that is definitely not forming in India today is tillite. Glaciers could be found only in the Himalayas. The rocks in this rock column were found farther south and over an extensive area. They imply that almost the entire country was covered by ice. A similar environment is not possible today because of India's proximity to the equator.

8. You have observed that both India and Antarctica have rocks that were formed in environments that were much different from the environments in those two places today. List as many explanations as you can to account for this situation.

The major idea that students should understand at this point is that at one time the environments of both continents were quite different from today. Students should be encouraged to list any and all possible explanations.

9. Examine the rock columns from all four areas. List each similar order of rock layers that you can find.

10. One similarity that you will have noticed is the presence of basalt at the top of each of the rock columns. How is basalt formed?

11. Can you tell whether the basalt in each of the areas was formed at the same time? Explain. How about the coal? Explain.

Emphasize the point that, with the information available, it cannot be determined whether or not either the basalt lavas or the coals formed at the same time. The answer to both of these questions is no.

Part B. How Old Are The Rocks?

Materials

Colored pencils
Worksheets 1 and 2

Procedure

You found out in step 11 above that you really could not tell from the information provided you whether layers of similar rock types from different areas were formed at the same time. If you could find out the ages of these rocks, then you could determine whether the same environment existed in all four areas at the same time. You could also learn whether the environment changed in the same way in each of the four areas. This would certainly tell us something interesting about the history of the areas.

To determine the age of a sedimentary rock, fossils must be present. Each fossil species is always the same age wherever it occurs. In this way, the age of the rock that contains the fossil can be determined. All rocks containing that fossil are the same age even if found in different places and even if they are different kinds of rocks. Matching the ages of rocks by using fossils is known as correlation.

The plant fossils found by Scott's expedition have been identified by geologists as belonging to the genus Glossopteris. These plants have been found in coal seams in many places around the world. Glossopteris is Permian in age.

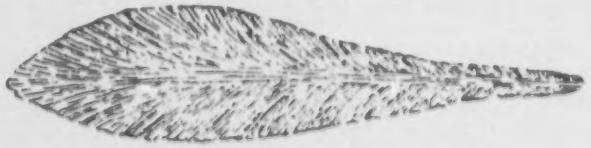
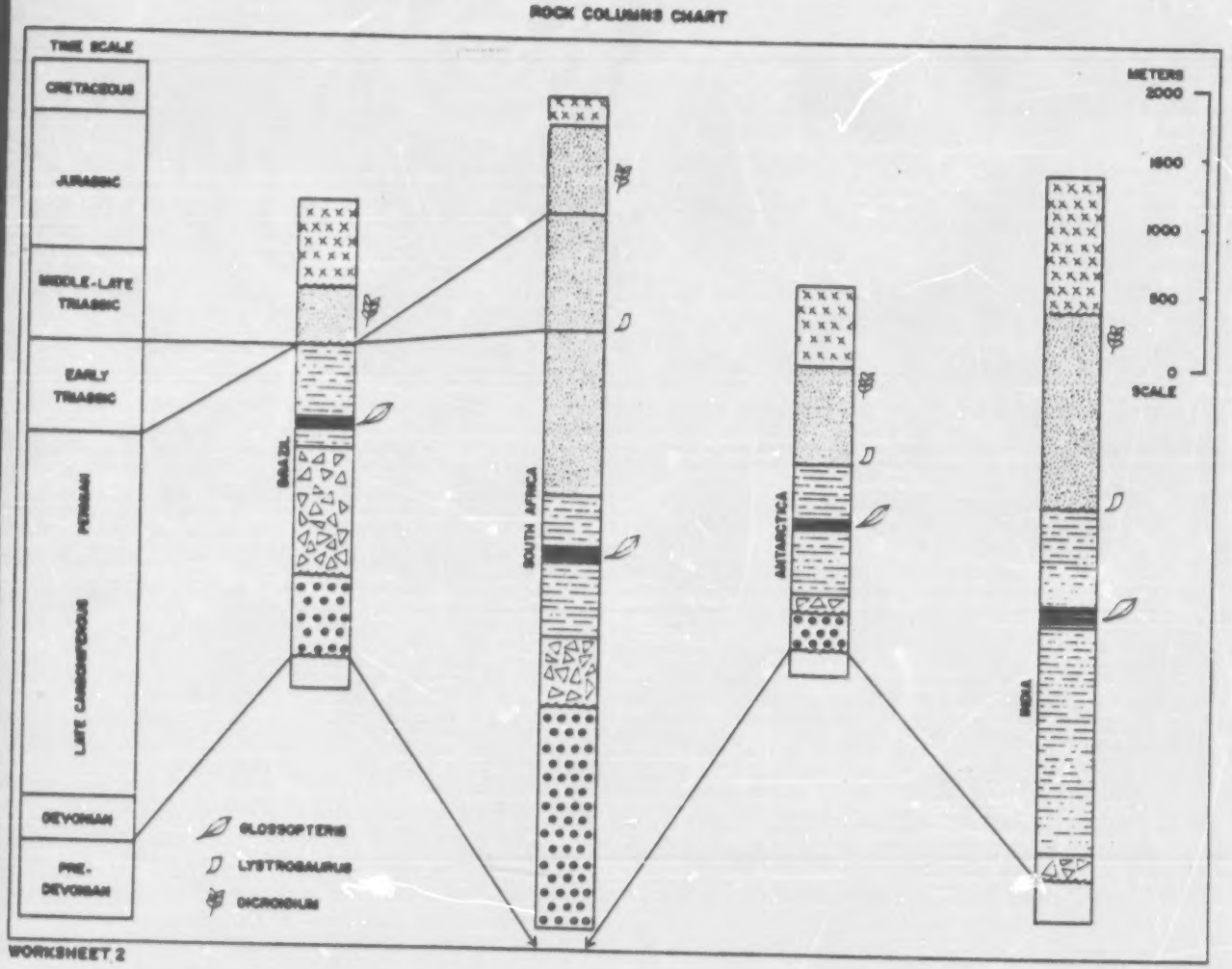


Figure 1 — The *Glossopteris* plant lived during the Permian age, about 270 million years ago. (Redrawn from Hurley, P. M., 1968, *Scientific American*)

1. The rock columns are from four different areas. Locate these areas on the outline map of the world (Worksheet 1) and label them.

2. Color in each time period in the time scale of the Rock Columns Chart (Worksheet 2) with a different color. These distinctive colors will then be used to mark the ages on the four rock columns. Color in the beds containing the

183


ROCK COLUMNS CHART
TIME SCALE
CRETACEOUS
JURASSIC
MIDDLE-LATE TRIASSIC
EARLY TRIASSIC
PERMIAN
LATE CARBONIFEROUS
DEVONIAN
PRE-DEVONIAN
BRAZIL
SOUTH AFRICA
ANTARCTICA
INDIA
METERS
2000
1500
1000
500
0
SCALE
GLOSSOPTERIS
LYSTROSAURUS
DICROIDIUM
WORKSHEET 2

Glossopteris fossils with the color indicating Late Carboniferous or Permian. Place a "G" on your world map where Glossopteris has been found.

3. How can you explain the presence of Glossopteris in four such widely spread areas?

Supporters of continental drift have used the presence of Glossopteris as evidence of the former contiguity of the four areas. They argue that the plant could not have migrated over such extensive areas of the ocean. Opponents, however, suggest that seeds could have been carried by ocean currents or maybe the wind. This type of migration accounts for the presence of native flora and fauna of volcanic islands such as the Hawaiian Islands.

4. Fossilized pollen found in the tillites indicates that they are either Late Carboniferous or Early Permian. Color in the tillites with the correct color.

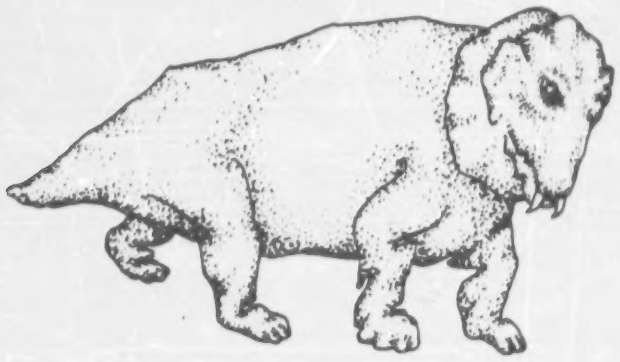


Figure 2 — *Lystrosaurus* was a reptile which lived in India and South Africa during the Early Triassic age. (Redrawn with permissoi, courtesy of Edwin H. Colbert.)

In 1967, a geologist with the Ohio State University Institute of Polar Studies found a jaw fragment belonging to an ancient amphibian, not far from where Scott's party found the coal seams and the Glossopteris fossils. A team from the Institute of Polar Studies, encouraged by this find, returned to the same area in 1969 with a specialist in identifying fossil amphibians and reptiles. On the first day of the expedition, the team's leader, David Elliot, climbed a bluff near the base camp. He found an ancient stream channel deposit containing bones and teeth. Edwin H. Colbert, the specialist in amphibian and reptile fossils, identified a jaw-bone he found there later as being that of Lystrosaurus, a reptile previously found in India and South

Africa in rocks of Early Triassic age. It was a land reptile, not adapted for swimming long distances.

5. Color in those sediments containing Lystrosaurus with the appropriate color indicating their age.

6. Place an "L" on your world map in those areas where Lystrosaurus has been found. How can you explain the presence of a reptile, like Lystrosaurus, in four such widely separated areas?

It is much more difficult to argue that a land reptile, such as Lystrosaurus, could have migrated across the oceans to populate such widespread areas. When Lystrosaurus was found in Antarctica along with four other species of land reptiles, most paleontologists became convinced that continental drift was a viable theory.

7. Certain shellfish found in the marine sandstone of Brazil, South Africa and Antarctica have been determined to be of Devonian age. Color in these portions of the rock columns with the appropriate color. Dicroidium is a plant fossil restricted to the Late Triassic. Color in the portions of the rock columns containing Dicroidium.

Igneous rock, such as the basalt at the top of each of the rock columns, can be dated through a process called radiometric dating. In this procedure, the amount of certain radioactive nuclides in the rock is measured.

8. The basalt in Brazil and India is of Cretaceous age. In South Africa and Antarctica it is from the Jurassic period. Color in the basalt in the rock columns with the color indicating its age.

9. Now correlate the rock units for each area. Draw lines between the columns indicating the boundary between each of the ages. The line dividing the basement (pre-Devonian) from the Devonian has already been drawn in for you. The Early Triassic layers of Brazil and South Africa have also been correlated. HAVE YOUR TEACHER CHECK YOUR CORRELATIONS BEFORE YOU CONTINUE.

10. During what age were glaciers present in all four areas?

11. When were three of the areas covered by the sea?

12. During what age did all four areas have extensive swamps?

13. How can you explain that in the past the environments of these four areas, as indicated by their rocks, were very

similar when today their environments are so different?

Students should come to the conclusion that the evidence they have been studying in this investigation leads to the idea that these four areas were part of a single continent from at least Devonian through Jurassic.

In this investigation you have studied some of the evidence that leads geologists to believe that at one time India, Antarctica, Africa, Australia, and South America were all part of one continent.

14. From your study of plant and animal fossils, determine the most recent time that Gondwana could have been a single continent.

15. When did extensive volcanic activity first occur in Gondwana?

16. When do you think Gondwana began to break up?

Summary Questions

1. How do geologists determine the type of environment that existed in an area during the past?

2. A geologist found several layers of sediment exposed in a river bank. Which was the oldest layer? The youngest?

3. What is meant by correlation of rock layers?

4. Describe the evidence for the former existence of the continent Gondwana.

References

Crawford, A. R. "Great Gondwanaland." Science, v. 184, p. 1179-81, 1974.

"Final Piece of the Gondwana Game." Science News, v. 106, p. 54, 1974.

"Geologists assemble the biggest puzzle of all: Gondwanaland." Science Digest, v. 76, p. 72-77, 1974.

Plate Tectonics and Evolution

by
Ronald F. Pauline, 1979

Introduction

When land masses are separated and drift to different positions on the earth, their climate will naturally be affected. This climatic change will also have an effect on the evolution of plants and animals.

When land masses collide and different plants and animals are intermixed, the results will also affect the evolution of life on this new, larger land mass.

Objectives

After you have completed this investigation, you should be able to predict:

1. How climate of a land mass changes as it moves.
2. How this new climate affects the evolution of plants and animals.
3. How intermixing of different plants and animals will affect evolution.

Part A

Procedure

In figure 1, two distinct land masses are shown. The large land mass A is located on the equator and has a rain forest type vegetation. The abundant rain and warm weather have produced enough food to support a large population: small tree climbing mammals; small burrowing mammals and small flying animals which are herbivores; large cat-like mammals which are carnivores; very large flying reptiles which are omnivores, and finally, crocodile-like reptiles that live in swamps. This is the population of land mass A. As can be seen, mammals have replaced the reptiles as the dominant species.

1. What would be the main diet of the small mammals?

Fruits, berries, leaves, etc. from the abundant vegetation.

2. The small mammals would, in turn, be the main diet of which animals?

The cat-like animals and the large flying reptiles.

The crocodile-like reptiles would, of course, feed on warm water fish and any small mammals that they could catch.

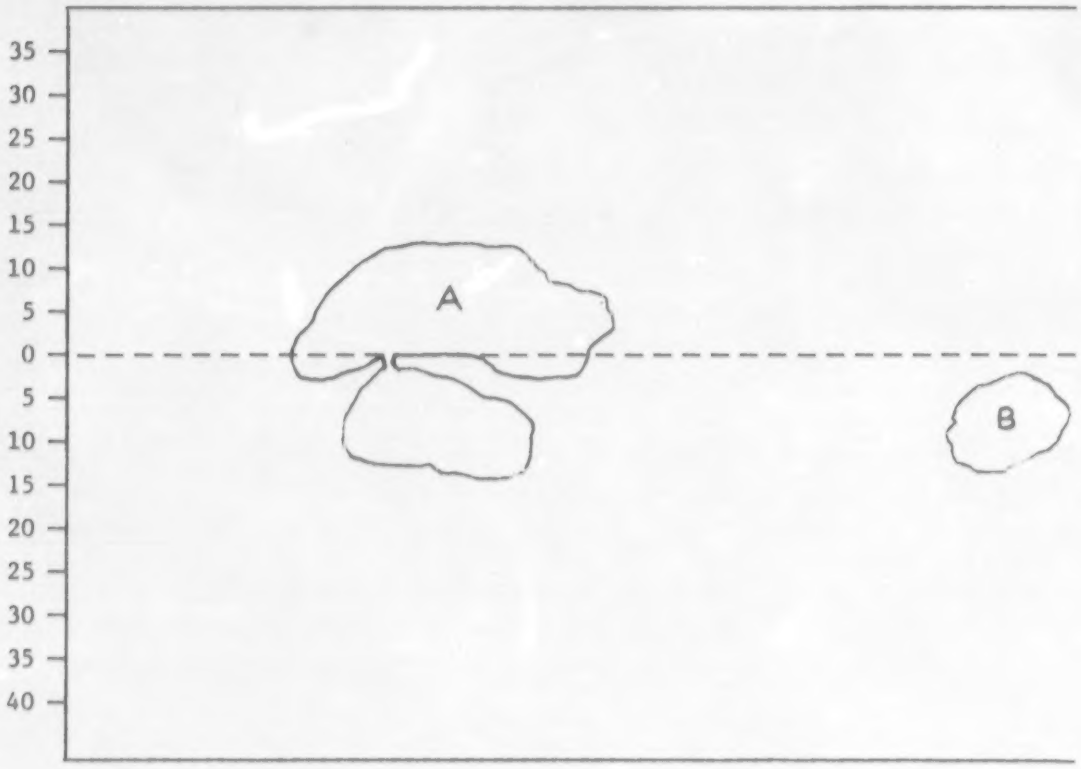


Figure 1

Land mass B has approximately the same type vegetation as A but is populated by large dinosaur-like reptiles. There are large and small herbivores feeding on the lush vegetation and large carnivores feeding on the plant eaters. On this land mass the small number of mammals is clearly dominated by the large reptiles.

3. How could you acoount for the fact that the two land masses so alike in vegetation and climate would be populated by animals so different?

Since they are separated, the evolution is along random genetic evolution. The dinosaurs and mammals evolved separately.

Part B

Procedure

At a point in time, the large mass begins to split apart and move in the directions indicated. Land mass B is also drifting in the direction indicated in Figure 2.

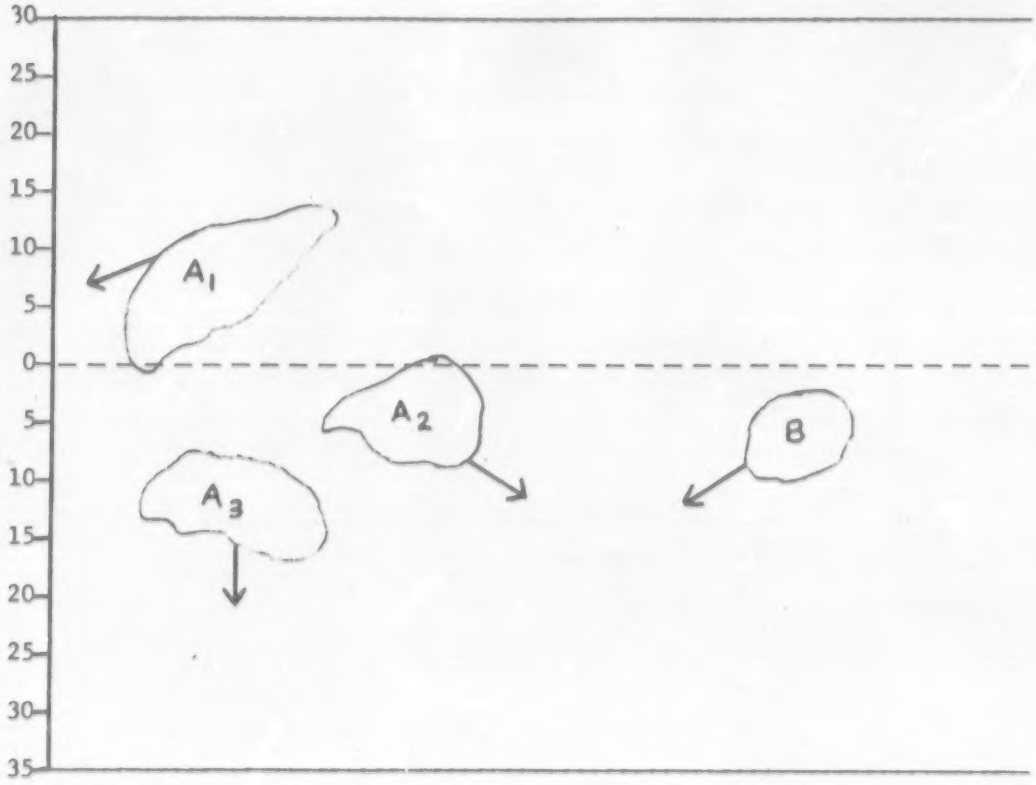


Figure 2

4. How is the climate of Land mass A_3 changing as it migrates rapidly south-southeast?

   It would be getting cooler as it nears the temperate zone.

5. How would this affect the vegetation?

   It would become less jungle like and more temperate-like: no underbrush present, with more deciduous trees.

6. Would the rainfall of A_3 be more or less than originally?

   Less.

7. How would the climate of A_1 be affected?

Very little since it is still at the same latitude.

Part C

Procedure

In Figure 3, the land masses continue to move in the directions indicated. The land masses A_2 and B have collided while A_1 is still at the same latitude and A_3 has migrated far south.

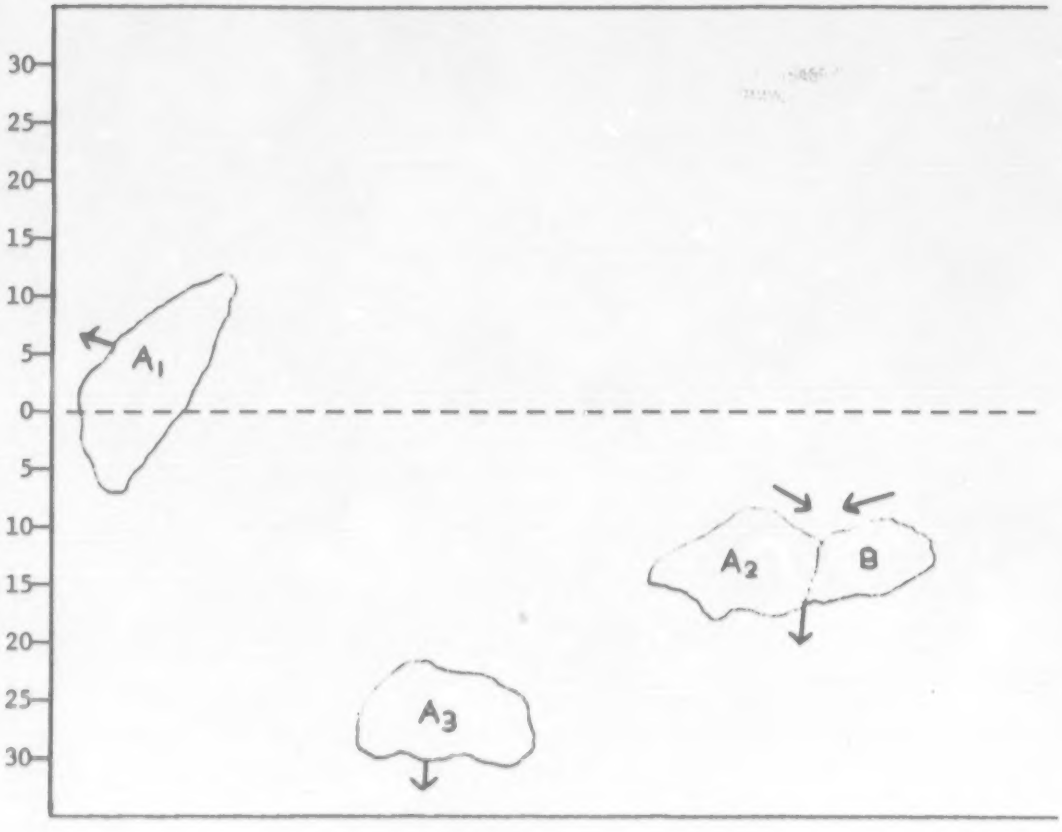


Figure 3

8. Will the climate of A_1 change from its original climate? Why?

No. It is still in the original position astride the equator.

9. What will the climate of A_3 be like now?

Dry since it is at 30^0 where the air mass falls back to earth. It would be much cooler than it originally was.

10. What type of vegetation will A_3 now have?

No jungle. More broad leaf deciduous trees, some grassland.

11. Describe how the animal population has changed from the original population on A_3.

The mammal population will stay about the same but probably the large cat-like mammal will have a lower population since less food is available. The large flying reptile will disappear along with the warm water crocodiles.

The climates of A_2 and B will have also changed. They will still be fairly hot but there will be much less rainfall. The vegetation will still be plentiful as far as trees are concerned but the undergrowth will be gone. The dinosaur-like reptiles from B will now be intermixed with the mammals of A_2.

12. Which animal species would you think would reproduce with more frequency; the large dinosaurs or the smaller mammals?

Smaller mammals

The dinosaurs would initally have plenty of food but it would start to become more sparse as both the mammals and reptiles would compete for it.

13. Which species would need less food to survive and why?

Mammals, because they are smaller and would need less food.

14. Do you think the dinosaurs could catch the smaller mammals to eat them? Why or why not?

No, because the mammals would be too quick to catch.

15. Knowing the above information which species do you think would began to die out and finally become extinct? Why do you say that?

The dinosaurs; they would have less food to eat--less plants for the herbivores and less plant-eating dinosaurs and fewer mammals for the carnivores.

Summary Questions

1. Why do you think that fossils of animals that live in the tropics have been found in Antarctica?

   Antarctica once was at the equator and drifted southward.

2. Would you expect to find the same type of fossils in eastern South America and western Africa?

   Yes.

   Why?

   From the map it looks like they were once connected and have drifted apart.

Drifting Volcanoes

by
Richard N. Passero and Caspar Cronk, 1978

Introduction

We all know that volcanoes erupt at different locations through the world, but have you ever wondered why they erupt where they do? You may have, but have you ever wondered if they remain in the same location forever or if any volcanoes ever permanently stop erupting? In this exercise you should discover the answers to these questions.

The active volcanoes of the world are shown on the map in Figure 1. By "active" we mean those 500 or so volcanoes that have erupted within the last 400 years or, in other words, those for which we have pretty good records. Most active volcanoes on the continents are located within 200 to 300 kilometers of the sea. Those around the Pacific Ocean form what is called the "circle of fire" and include volcanoes such as Mt. St. Helens, Mt. Lassen and Mt. Fuji.

There are many more volcanoes in the world, of course, but they have not been active recently. Beginning in the early 1950's exploration of the oceans by ships such as the Glomar Challenger have revealed that volcanoes are also very common beneath the sea.

Many of the volcanoes in the oceans are located on submarine volcanic mountain ranges (ridges) but others are located off the ridges. The ages of the rocks on these volcanic islands, tell when the volcanoes erupted the lavas which form the islands.

Objectives

Upon completion of this activity you will be able to:

1. Give the names of active volcanoes and where they are located.
2. Tell why they are located where they are, what determines how long they are active, and whether they have always been in their present locations.
3. Graph data and perform some simple mathematical calculations.

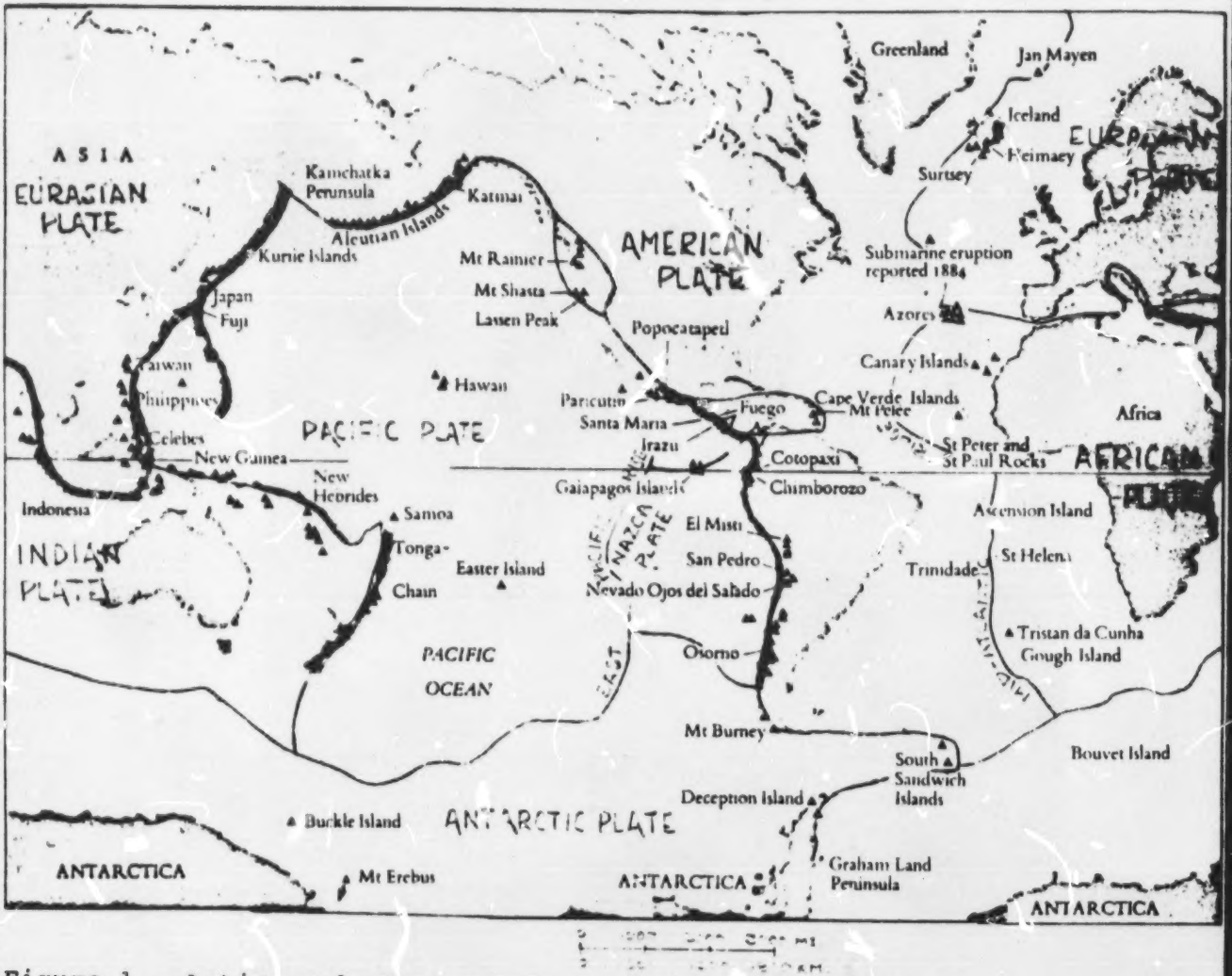


Figure 1.--Active volcanoes of the world and their location on the crustal plates. (Adapted from Francis, 1976.)

Materials

Map of the Atlantic Ocean Basin published by the National Geographic Society, 17th & M. Streets, N.W., Washington, D.C. 20036

Part 1

Procedure

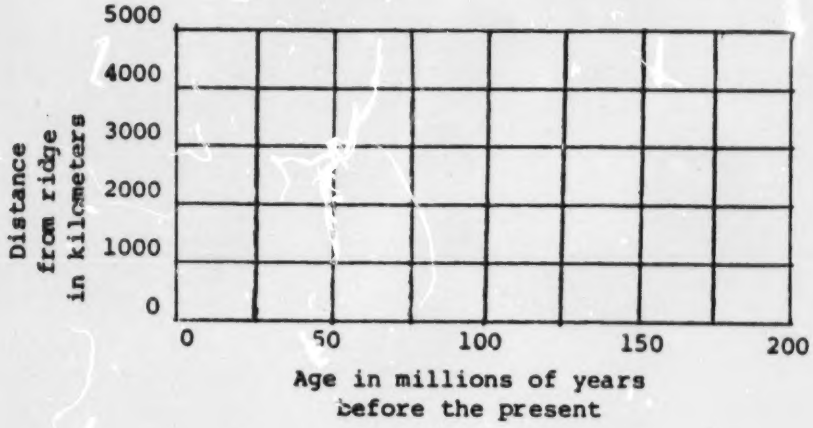
1. See how many of the names of the volcanoes in Figure 1 you can pronounce.

2. Complete column three of Table 1 below by measuring the distance between each volcano and the mid-Atlantic rift, on the map of the Atlantic Ocean Basin.

Table 1. Volcanoes in the Atlantic Ocean Basin

Name	Age in million years	Distance from rift
Jan Mayen Island	10	_____
Iceland	10	_____
Faroes	50	_____
Azores	20	_____
Canary Islands	32	_____
Cape Verde Islands	150	_____
Sao Tome	120	_____
Ascension	1	_____
St. Helena	20?	_____
Tristan Da Cunha	1	_____
Bouvet Island	1	_____
Bermuda	36	_____
Bahamas	120	_____
Fernando De Noronha	120	_____
Falkland Islands	1,100?	_____

3. Using the data in Table 1, plot the age and distance of each volcano in the graph below:



4. Figure 2 is a map of the ages and locations of rocks found at the bottom of cores obtained by the Deep Sea Drilling Project. Determine the distance from the ridge for each sample within the boxes drawn on the map. Plot distance and age of these rock samples on the graph above, using a different symbol than that used for the volcanoes.

5. How do the two lines compare?

6. What does this graph tell you about the general relationship between the age of the volcanoes and other rocks in the Atlantic Ocean and their distance from the Mid-Atlantic Ridge?

7. Now draw arrows on Figure 2 from youngest rocks to oldest. Suggest a reason for your answer to Question 6.

8. Identify the oldest volcanoes in Table 1. Divide the distance of each volcano from the rift by its age.

   a. $\frac{\text{distance from ridge}}{\text{age of volcano}}$

   b. $\frac{\text{distance from ridge}}{\text{age of volcano}}$

9. What do these figures tell you about the volcanoes?

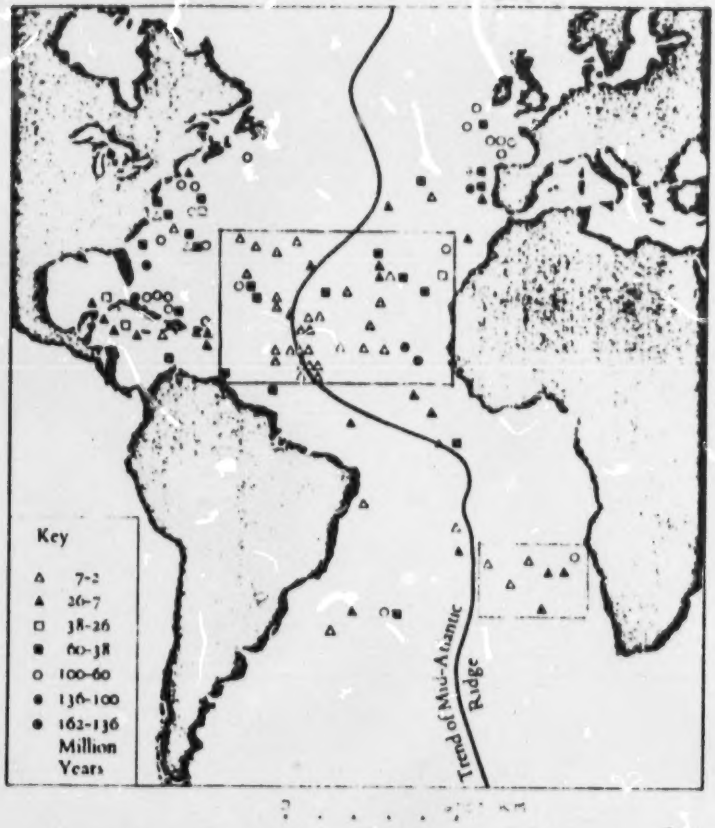


Figure 2.--This JOIDES map shows the ages of specimens collected from different points on the Atlantic Ocean floor; the specimens furthest from the ridge are the oldest, broadly speaking (from Francis, 1976).

Part 2

Procedure

As shown in Figure 1, most active volcanoes are located on the margins of the plates, but a few are located within the plates. There are 122 active volcanoes not located on plate boundaries; 53 are in the ocean basins and 69 are on the continents. The volcanoes are referred to as "hot spots" and are thought to originate from hot plumes of magma rising from a few hundred kilometers deep in the mantle. The Hawaiian Islands in the Pacific Ocean are thought to be located over a hot spot.

1. The only active volcanoes in the Hawaiian Islands are on the Island of Hawaii. The age of the islands increases from Hawaii to the northwest as shown in Figure 3. Plot the Hawaiian volcanoes and the Emperor Sea Mounts on the graph.

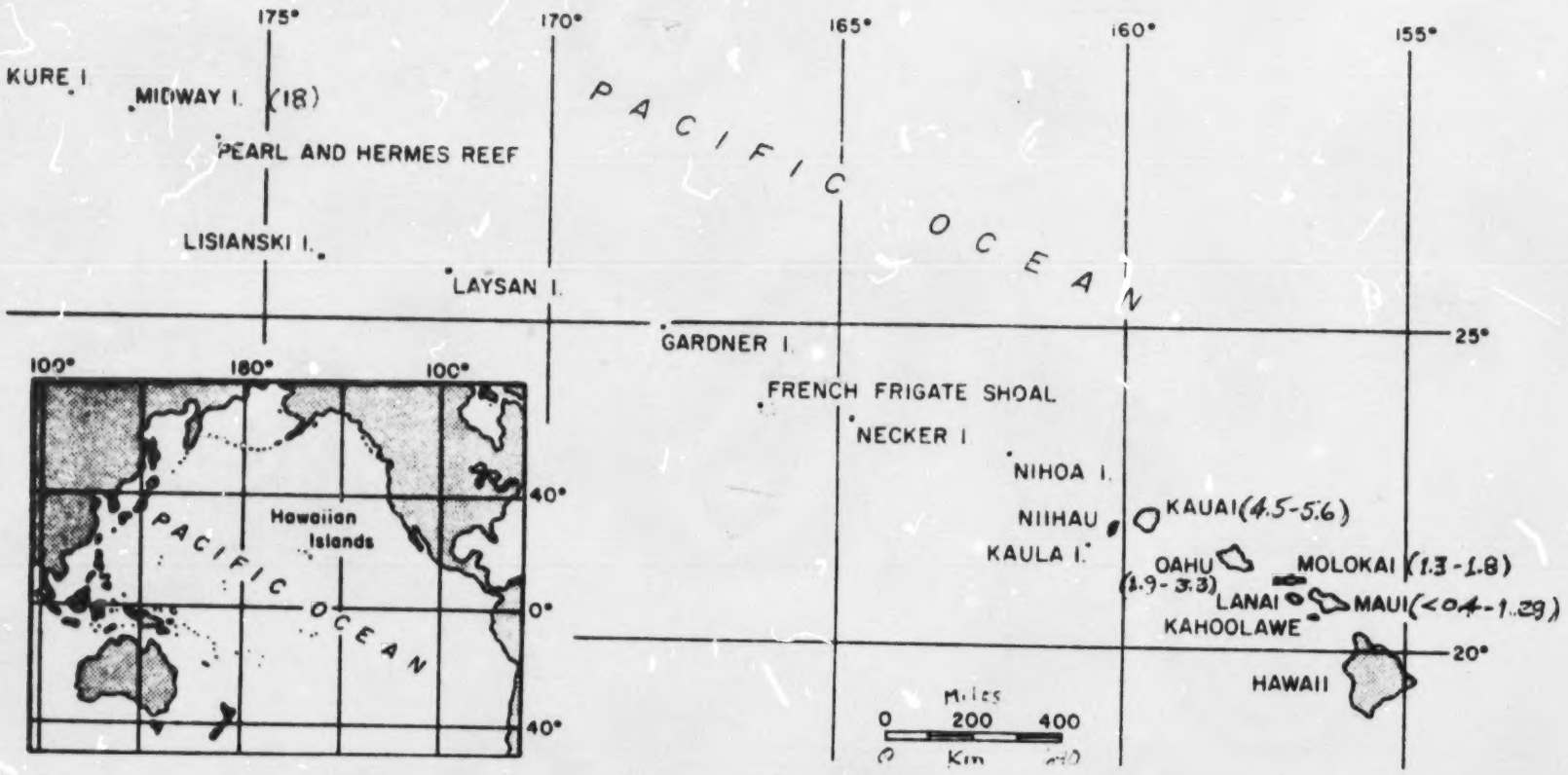
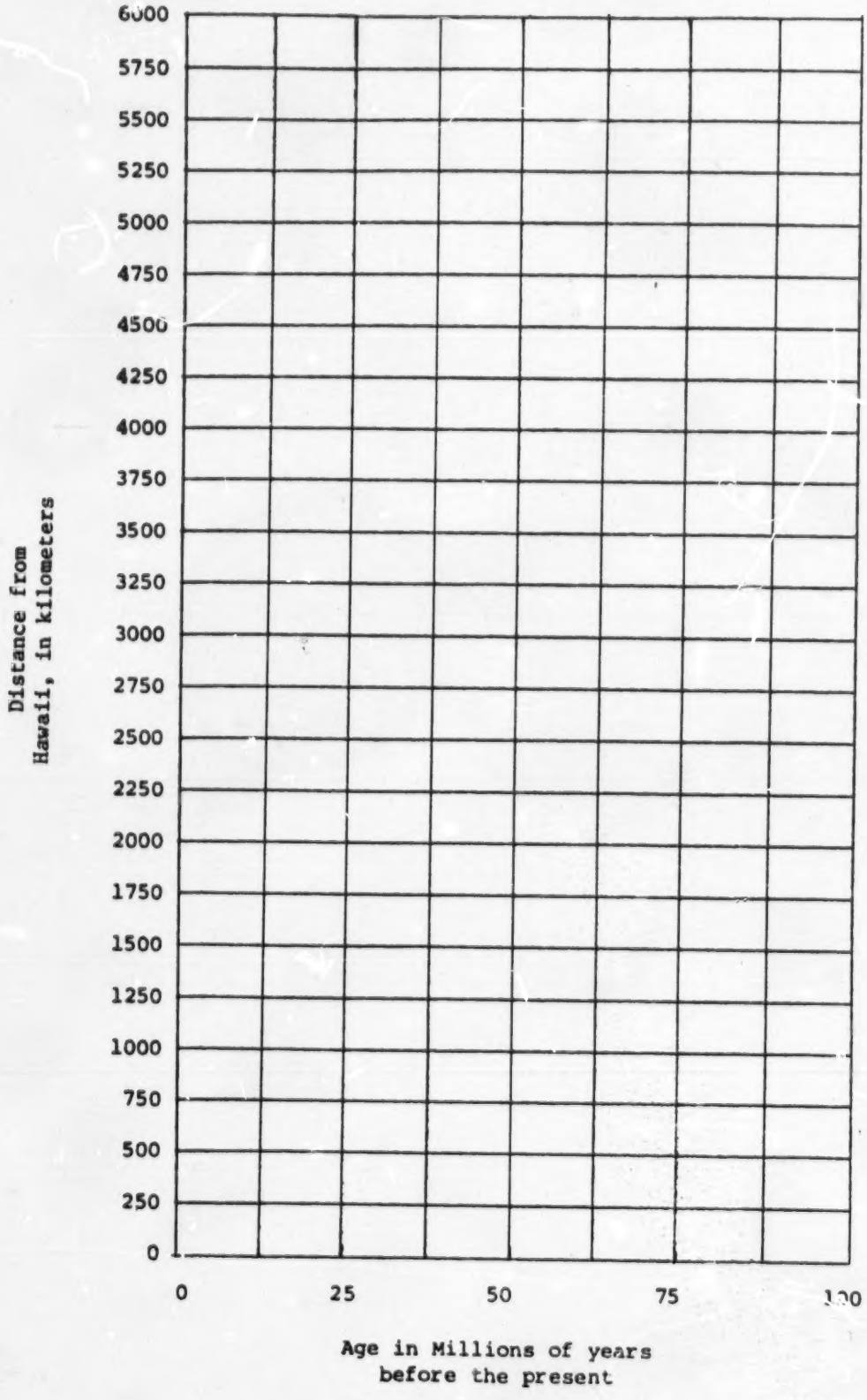


Figure 3.--Map of the Hawaiian Archipelago. The small inset shows the location of the islands in the Pacific Ocean. (from MacDonald and Abbott, 1970.)

202


6000
5750
5500
5250
5000
4750
4500
4250
4000
3750
3500
3250
3000
2750
2500
2250
2000
1750
1500
1250
1000
750
500
250
0
Distance from
Hawaii, in kilometers
0
25
50
75
100
Age in Millions of years
before the present

How does this graph compare with the one you drew for the Atlantic Ocean?

2. Calculate the rate of movement of the Hawaiian Islands as you did for the islands in the Atlantic Ocean.

3. Can you suggest a reason why the islands increase in age to the northwest? Remember that the volcanoes on all the islands except Hawaii are extinct (no longer active). How might this be related to the movement of the Pacific Plate?

4. Note that the Emperor Sea Mounts are at an angle to the Hawaiian Islands. Can you suggest a reason for this?

Extensions

1. Go to the library and write a short story about the name of a volcano that sounds interesting to you.

2. What might be the ultimate fate of the Hawaiian Islands? How long will it take for this to happen?

3. What other islands in the Pacific would you expect to show the same age relationship as the Hawaiian Islands?

References

Francis, Peter, 1976, Volcanoes, Penguin Books, 386 p.

Grove, N., 1973 (July), "A Village Fights for its Life," National Geographic Magazine, 144: 40-67.

Macdonald, G. A., 1972, Volcanoes, Prentice-Hall, Inc. 510 p.

Macdonald, G. A., and A. T. Abbott, 1970, Volcanoes in the Sea, University of Hawaii Press, 441 p.

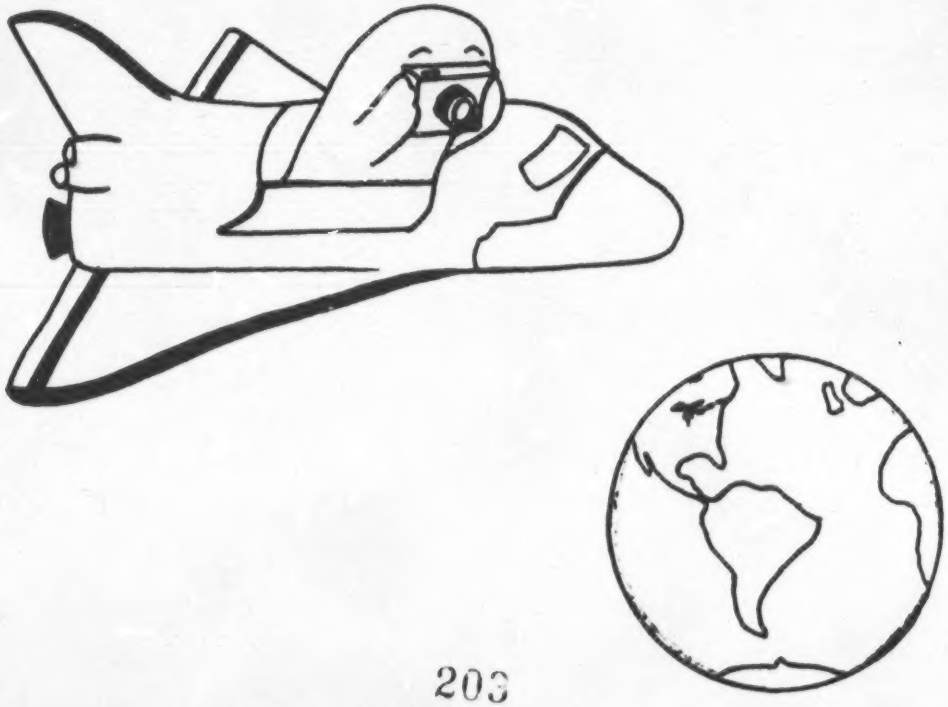
Poole, L., 1962, Volcanoes in Action: Science and Legend, McGraw-Hill, 79 p.

Scientific American, 1976, Continents Adrift and Continents Aground, W. H. Freeman, 230 p., especially Burke, Kevin C. and J. Tuzo Wilson, 1976, "Hot Spots on the Earth's Surface," pp. 58-69.

202

CHAPTER V

USES OF SPACE PHOTOGRAPHY



RESOURCES

Space photography has provided us with an entirely new perspective, not only of the other planets and their satellites in our solar system, but also a much more detailed look at the surface of our own earth. This photography can be of enormous use to the earth science teacher. This chapter was especially designed to bring attention to the potential uses of the imagery provided by Landsat, Voyager and other space probes. NASA has published several volumes of photography with the expressed intent to make it more available to teachers. Below are listed a number of these publications:

Apollo Over the Moon: A View from Orbit, SP-362, is a collection of 264 photographs of the lunar surface taken with Apollo panoramic and metric camera systems to aid in the effort of Moon mapping. The photos are of high resolution and accuracy and show the surface of the Moon in great detail; all are accompanied by detailed captions. Clothbound, 267 pp. $9.25 (Stock No. 033-000-00708-6).

Images of Mars, SP-444, presents images from one of NASA's most extraordinary space missions. The photographs and texts provide an elegant look at the planet Mars as revealed by the Viking spacecraft since their arrivals and landings in 1976. 32 pp., $2.25.

The Martian Landscape, SP-425, is a hard-cover volume describing the Viking Mission from planning and designing, through testing, to dazzling success. Written by the Viking Lander Imaging Team, the book includes 200 high-quality photographs--mosaics, panorama, close-ups--of which 22 are in color. $12.00 (Stock No. 033-000-00716-7).

Voyager to Jupiter, SP-439, is the story of the Voyager mission and its people, and the spacecraft's findings as it flew by Jupiter in the spring and summer of 1979. The text relates the excitement of the flyby and presents the science of the mission in a manner easily understood: the photographs provide a spectacular view of the Jovian system. Paperbound, 211 pp., $7.50.

Mission to Earth: Landsat Views the World, SP-360 consists largely of 400 color plates of Landsat imagery. Each has been selected to show surface features and has an accompanying caption locating and describing significant features. (Stock No. 033-000-00659-4).

Educator's Guide for Mission to Earth: Landsat Views the World, is a 60-page book designed to accompany NASA SP-360, Mission to Earth: Landsat Views the World; written for junior and senior high

school teachers of the sciences, social studies, and geography, the guide helps teachers to fully utilize the large volume of Landsat material. $2.50 (Stock No. 3300-00735-3).

Where To Write For Services

NASA publications should be ordered from the Superintendent of Documents, Government Printing Office, Washington, DC 20402. Publication lists, film lists, and information about other services are available from the Educational Office at the NASA center serving your state. See the list below. There are special resource centers for educators at the Kennedy Space Center, Lewis Research Center, and Alabama Space and Rocket Center, Huntsville, AL.

NASA Ames Research Center
Moffet Field, California 94035
Alaska, Arizona, California, Hawaii, Idaho, Montana, Nevada, Oregon, Utah, Washington, Wyoming.

NASA Goddard Space Flight Center
Greenbelt, Maryland 20771
Connecticut, Delaware, District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont.

NASA Lyndon B. Johnson Space Center
Houston, Texas 77058
Colorado, Kansas, Nebraska, New Mexico, N. Dakota, Oklahoma, S. Dakota, Texas.

NASA John F. Kennedy Space Center
Kennedy Space Center, Florida 32899
Florida, Georgia, Puerto Rico, Virgin Islands.

NASA Langley Research Center
Hampton, Virginia 23665
Kentucky, N. Carolina, S. Carolina, Virginia, West Virginia.

NASA Lewis Research Center
21000 Brookpark Road, Cleveland, Ohio 44135
Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin.

NASA George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812
Alabama, Arkansas, Iowa, Louisiana, Mississippi, Missouri, Tennessee.

Using Landsat Imagery to Study Earth's Surface Features

Adapted from activities in the
Educator's Guide for Mission to Earth: Landsat Views the World,
National Aeronautics and Space Administration, 1978.

by
Victor J. Mayer

Introduction

The marvels of space age photography have made available to us views of the earth never before possible. How can this photography help us to understand the surface features of the earth and how they are changing?

Objectives

When you have completed this activity you will be able to use Landsat images to:

1. Identify different patterns of drainage.
2. Locate structural and topgraphic features.
3. Identify volcanic features and determine their impact upon land use.
4. Map surface and tectonic features.

Materials (see resources for complete reference)

Mission to Earth: Landsat Views the World.

Part 1. Identification And Study Of Drainage Patterns.

Procedure

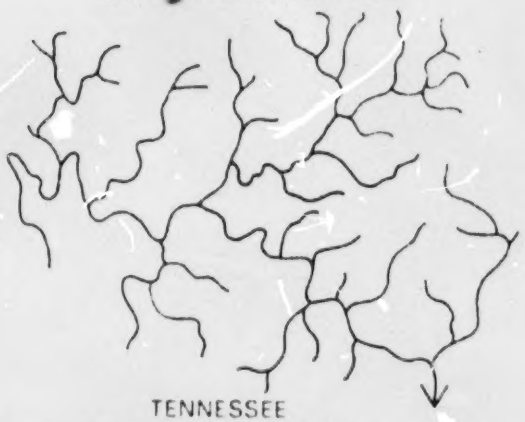
Different types of underlying geologic structure result in various types of drainage patterns on the earth's surface.

The four major drainage patterns are illustrated below.

The most common drainage pattern is the dendritic. This tree-like pattern usually forms on flat or nearly flat-lying material which is relatively uniform in its ability to resist erosion. Radial drainage occurs around a central dome or mountain which has streams flowing outwardly in all directions. Trellis drainage is a trellis-like pattern of relatively straight

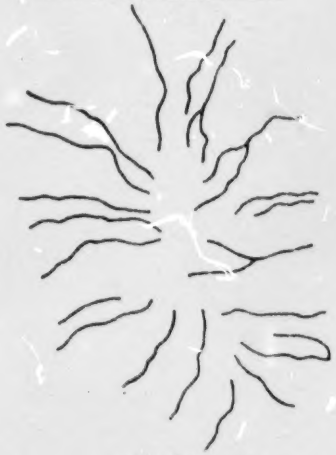
streams which meet each other at right angles. This usually occurs where there are alternating linear ridges and valleys formed by faulting or folding. Annular drainage, like the trellis, is structurally controlled, but develops over well-defined domes or basins, forming curved rather than rectilinear patterns.

DENDRITIC DRAINAGE



TENNESSEE
APPALACHIAN PLATEAU

RADIAL DRAINAGE



HAWAII MAUI
CRATER

TRELLIS DRAINAGE

TENNESSEE
VALLEY & RIDGE

ANNULAR DRAINAGE

OUACHITA MTS
(MODIFIED)

1. Using the above information and diagrams, identify as many different drainage patterns as possible on Landsat images. Try to associate each type of drain-

age pattern with the geologic structure of the area shown on the image. Suggested plates for this activity are:

a. Plate 205--Amazon River
b. Plate 276--Tigris and Euphrates River
c. Plate 301--Brahmaputra River
d. Plate 315--Yellow River
e. Plate 339--Zaire (Congo) River

Part 2. Locating And Identifying Gross Geological Features.

Locate in Mission to Earth. . . examples of the geological features listed below:

Feature	Suggested Plates in Mission to Earth. . .
a. Fault	125 - Monterey Bay
b. Volcano	135 - Island of Hawaii
c. Lineament	18 - Atlanta, GA
d. Finger Lakes	8 - Finger Lakes, NY
e. Canyon	76 - Colorado Rocky Mts.
f. Plateau	77 - Uranium Country, Utah--Colorado
g. Mesa	84 - Northwest New Mexico
h. Karst topography	246 - Dalmatian Coast of Yugoslavia
i. Lava flow	101 - Southern Idaho
j. Alluvial fan	133 - Imperial Valley, CA
k. Graben	83 - North-Central Arizona
l. Cuesta	84 - Northwest New Mexico
m. Anticline	99 - Bighorn Mts., Wyoming
n. Syncline	14 - Harrisburg, PA
o. Geyser field	98 - Yellowstone National Park

Note: You may need to refer to the caption accompanying each image for additional clues to help identify these features. Atlases and other maps will also be very useful in completing this activity.

Part 3. Studying Volcanism And Its Impact Upon The Environment.

1. Define the following types of features which result from or are associated with volcanism. (Note that definitions may be found in Mission to Earth. . . Appendix B, "Glossary of Technical Terms," pp.443-451).

Feature	Suggested Plates
a. Crater Lake	193 - Managua, Nicaragua
b. Caldera	111 - Cascade Range, Oregon
c. Active volcano	241 - Italy

d. Dormant volcano 322 - Dormant volcano awakens
e. Lava flow 101 - Southern Idaho
f. Strato-volcano 110 - Portland, Oregon
g. Igneous intrusion 85 - Canyon Lands, Southeast Utah

2. Find examples of these features from Mission to Earth. . .

3. Select one image from among those showing volcanic features and do the following:

   a. Observe the land use and other geologic and/or geographic conditions of the area shown on the image. (Note that these areas tend to be heavily vegetated).

   b. Prepare a brief discussion on the impact of volcanic activity in the area. Include in your discussion any indication of how man is using the area and why it is being used.

Part 4. Locating Surface Features.

1. Pick one of the images listed below:

Finger Lakes, New York	(8)
Harrisburg, Pennsylvania	(14)
Atlanta, Georgia	(18)
Nashville Dome and Basin	(29)
Colorado Rocky Mts.	(76)
Uranium Country, Utah-Colorado	(77)
North-Central Arizona	(83)
Northwest New Mexico	(84)
Canyon Lands, Southeast Utah	(85)
Grand Canyon, Arizona	(87)
San Rafael Swell, Utah	(91)
Yellowstone National Park	(98)
Bighorn Mts., Wyoming	(99)
Southern Idaho	(101)
Portland, Oregon	(110)
Cascade Range, Oregon	(111)
Basin and Range Country, Oregon and Nevada	(112)
Monterey Bay	(125)
Bay Area, California	(126)
Imperial Valley, California	(133)
Island of Hawaii	(135)
"Finger Lakes" of Alaska	(143)
Sierra Madre Orientale, Mexico	(184)
Managua, Nicaragua	(193)
Amazon River	(205)

Norway	(222)
Scotland	(225)
Pyrenees	(230)
Rhine and Ruhr Valleys	(237)
Italy	(241)
Dalmation Coast of Yugoslavia	(246)
Tigris and Euphrates Rivers	(276)
Tibetan Plateau	(299)
Brahmaputra River	(301)
Yellow River	(315)
Dormant Volcano Awakens	(322)
Southern Morocco	(323)
Atlas Mountains	(324)
Zaire (Congo) River	(339)
Afar Depression	(366)
Pilbara District, Australia	(379)

Overlay a piece of clear plastic or acetate over the image and trace or label as many faults, lineaments, and other geologic surface features as possible.

2. Check overlays for accuracy with a topographic or other geologic map of the study area. The descriptive caption which accompanies each image in Mission to Earth. . . should also be consulted for purposes of information and comparison.

Part 5. Mapping Tectonic Features And Rock Types.

Select several images from among those listed for Part 4 above.

1. Prepare two overlays for each image selected:

   a. Overlay 1 -- Identify tectonic features (faults, joints, pipes, and others.)
   b. Overlay 2 -- Identify major rock types (igneous, sedimentary, metamorphic) shown on the image.

2. Place both overlays on the image and do the following:

   a. Observe and briefly describe the relationship between the linear features and the rock types in the area studied.
   b. Using the caption accompanying each image and corresponding geologic maps, indicate whether the predominant rock types are igneous, sedimentary, or metamorphic.

3. Carry out further research and discuss the major geologic forces which were or are operating in the area studied, and which have affected the rock structure of the area.

Assessing Our Impact upon the Environment by using Landsat Images

Adapted from activites in the Educator's Guide for Mission to Earth: Landsat Views the World, National Aeronautics and Space Administration, 1978.

by
Victor J. Mayer

Introduction

Our activities in resource development, industrial use of land and residential development have had a significant impact upon the land's surface and the waters of the earth. Landsat imagery provides a unique source of information with which to determine the extent of this impact and the effects it is having upon natural systems.

Objectives

When you have completed this activity you will be able to use Landsat images to:

1. Identify and map categories of land use.
2. Identify structures and features we have built.
3. Observe ongoing changes in the environment.

Materials(see resources for complete reference)

Mission to Earth: Landsat Views the World

Part 1. Identifying And Mapping Categories Of Land Use.

1. Select an image from among the following:

Washington-Baltimore	(1)
Delmarva Peninsula	(4)
Harrisburg, Pennsylvania	(14)
Knoxville, Tennessee	(17)
Southern Florida	(25)
Mobile, Alabama	(27)
Cape Canaveral, Florida	(26)
Western Lake Erie	(32)
Chicago, Illinois	(38)
St. Louis, Missouri	(39)
Mississippi River Flood Sequence	(41,42)
Yazoo Basin, Mississippi	(45)

Texas-Louisiana Timberland	(46)
Mississippi Delta	(47)
Upper Mississippi River	(52)
Oklahoma Oil Country	(60)
Uranium Country, Utah-Colorado	(77)
Central Wyoming	(97)
Yellowstone National Park	(98)
Big Horn Mts., Wyoming	(99)
W. Wyoming-S.E. Idaho	(100)
Southern Idaho	(101)
U.S.-Canadian Border	(104)
Mono Lake, California	(124)
Bay Area, California	(126)
Los Angeles, California	(129)
Mississippi River Sequence	(142)
U.S.-Soviet Border	(150)
Winnipeg, Manitoba	(163)
Amazon River, Brazil	(205)
Bahia Blanca, Argentina	(215)
Zaragoza, Spain	(231)
World's Largest Lake	(260)
Ob River, Siberia	(266)
Arabian Oil Fields	(280)
The Ganges Delta	(300)
Brahmaputra River	(301)
Yellow River	(315)
African Land Practice	(336)
Sudan	(364)
Nile Delta	(367)

2. Develop a key or legend explaining the use of different colors to represent the different types of land use listed below:
   a. Farm land . . . . . Green
   b. Urban areas . . . . . Pink
   c. Recreational areas(such as National Parks). . . Red
   d. Airports and airfields. . . . . Black
   e. Woodlands . . . . . Yellow
   f. Water . . . . . Blue
   g. Transportation facilities . . . . . Orange

3. Create a simple land use map by placing a sheet of clear acetate over the image, outlining the boundaries, and coloring in the land use types with the colors given in the legend.

4. Use maps or other reference materials to check the land use maps. Note that the descriptive caption provided with each image in Mission to Earth. . . contains information which should be very useful in completing this activity.

Part 2. Using Landsat To Study Man's Impact On The Environment.

1. Select an image from among those listed in Part 1.

2. Identify and list as many man-caused features as are visible on the image. Indicate those features which reflect the impact of technological innovation and development, such as dams, waterways, irrigation facilities, and others. Examples of many of these can be found on the following plates in Mission to Earth:
   a. Plate 25 Southern Florida
   b. Plate 27 Mobile, Alabama
   c. Plate 38 Chicago, Illinois
   d. Plate 104 U.S.-Canadian Border
   e. Plate 280 Arabian Oil Fields

3. Using maps and/or other reference materials, discuss how technological innovations and human activities have affected the environment. Several examples which might be examined are:
   a. Plate 38 Chicago, Illinois
   b. Plate 104 The U.S.-Canadian Border
   c. Plate 336 African Land Practice
   d. Plate 367 The Nile Delta

Part 3. Observing Temporal Changes In The Environment.

Landsat imagery offers the advantage of showing changes occurring over a nine-day period. This has important implications for the study of temporal changes.

1. Compare any Landsat image(s) with already existing maps of the same area. You may want to select an image of your local area for study. Observe and make note of the changes which have occurred from the time the map was produced and the date the image was made.

2. Look for features, such as reservoirs, highways, lakes or new airports which have appeared or disappeared since the map was produced.

Africa, The Splitting of a Continent

by
William N. Green, 1979

Introduction

You have learned that continents and ocean plates are mobile because of the upwelling of mantle material at ocean ridges. This propels them along in a conveyor-belt fashion toward subduction zones. When you look at a map of the ocean floor, it is easy to visualize the areas of sea-floor spreading and areas of subduction. But are there any areas where crustal movements are just beginning?

One way in which a geologist can infer the beginning of a rift zone in a particular area is to look at outer space pictures to determine if any lineations (long, narrow, stretch features), of the continental crust are present. If a rift zone occurs under a continental plate, it might just rip the continent apart, forming a new ocean. This process is taking place today on the continent of Africa, around the Red Sea and the Great Rift Valley.

Objectives

Upon completion of this activity you will be able to:

1. Describe the tectonic history of the Red Sea and the Great Rift Valley.

2. Observe the location of normal faults which cause the graben structure of the rift between Africa and Arabia and suggest sites to drill oil wells.

3. Use LANDSAT images to observe the presence of rift structures and volcanoes in the great Rift Valley of Africa.

4. Plot earthquake epicenter locations to determine if seismic data supports rifting in Africa.

Materials

Mission to Earth: Landsat Views the World (See Resources)
Two 8 x 8" pieces of transparent plastic.
Marker
Magnifying glass
Map of Africa

Procedure

At one time in the earth's history, Africa and Arabia were joined along their border and existed as one continental block. Later, due to the development of a rift zone or an area of crustal thinning, the two continental blocks were separated allowing the Red Sea waters to flow in. There is disagreement among experts as to exactly when this process began to occur, with some estimates as long ago as 200 million years. Lately, data suggest a break-up date as recently as 45 million years ago. In either case, the gradual spreading of Africa and Arabia away from each other continues even today.

It has been proposed that the rifting process has extended down into the continent of Africa. This idea has been supported by limited data.

What is known for sure is that the structure of the crust in the area of the Red Sea is similar to that in other areas which have undergone rifting. The extension of the crust causes a type of fault called a normal fault which allows a block of crust to drop down causing a basin called a graben to form.

1. You can demonstrate the formation of a graben by using three books as on figure 1. Orient one book vertically between the short side of the other two books held horizontally. Now, release the tension on the vertical book and reapply it again quickly. Notice that the book dropped down in relation to the horizontal books much like the graben does when the crust of the earth is extended.

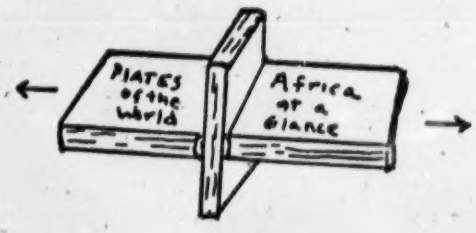


Figure 1. Graben Demonstration

The graben structure can be seen in a very high altitude photograph of the area as a broad basin, close to the edge of the sea. Refer to plate 273 in Mission.... Can you identify the graben?

Now, refer to figure 2, which is a profile view of a typical normal fault and graben structure. Be sure to notice that due to the gradual separation of Africa and Arabia, a series

of "stair step" blocks have developed. This part of the world is famous for its oil production and abundance of natural gas. Oil tends to migrate through porous rock layers until it comes up against a barrier where it collects as a underground pool.

2. Look at figure 2, and place an "X" on the diagram over any area where you think it might be a good place to drill an oil well.

3. In what rock unit would you expect oil to move?

4. In what area would you expect to find large, underground pools of oil?

5. What process causes the flanks of the Red Sea to be in a stair stepped arrangement?

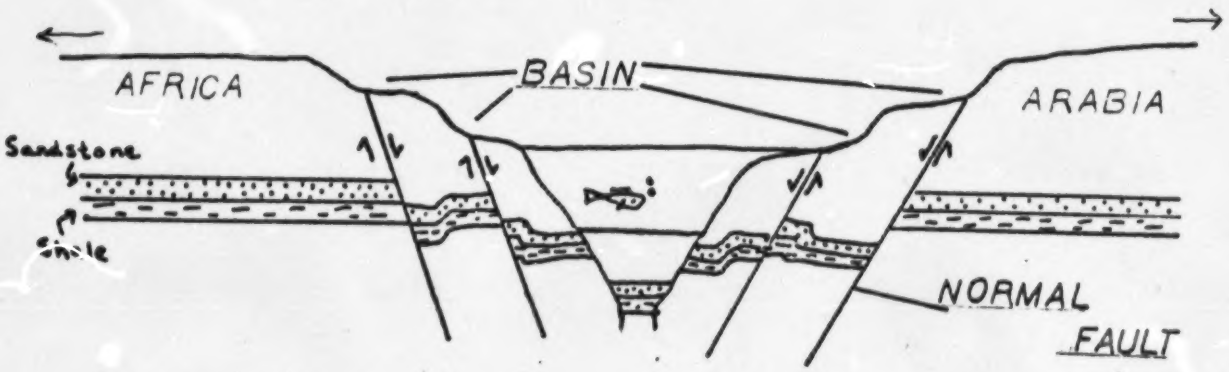


Figure 2. Graben Structure

Now that the structure of the northeast section of Africa has been established, it is important to try to see if the rifting process is occurring elsewhere on the continent. Three main features form as the result of rifting:

a) Lineations- long, linear (line-like) features caused by extension of the earth's crust.

b) Volcanoes- eruptions occur since the crust is thinned and fractured which allows magma to move up onto the earth's surface.

c) Earthquakes- vibrations of the crustal rocks as they are stretched and rifted.

The problem which any geologist faces is to try to collect as much information about an area as possible to help to see if the conditions are right for the occurrence of a rift zone. Of course, a good tool to help in this process is a series of

Landsat images. If lineations or volcanoes can be observed along a general trend on the African continent, and these are compared to earthquake data, perhaps a case can be made for a new, incomplete rift zone. In the following exercise, you will analyze data and come to a conclusion concerning this problem.

6. Refer to the map of Africa to determine the location of plates 359 and 361 from Mission.... This will orient you in relation to the Red Sea area. Your teacher will have the map at the front of the room for you to use.

7. Place a clear piece of plastic over one of the plates. Observe the image carefully to try to spot lineations. Trace over any lineations that you see with the marker. If you have trouble with this part, get help!

8. Do the lineations that you spotted trend in the same direction? _____ What direction do they run assuming the top of the picture is north? _____

9. Look at the Landsat image again very carefully. Draw a circle around any circular features which might be volcanoes. The caldera of the volcanoes may be filled with water. Repeat the process for the other Landsat image.

10. Plot the location of the earthquakes listed below on worksheet 1 by placing a dot on the map at each location:

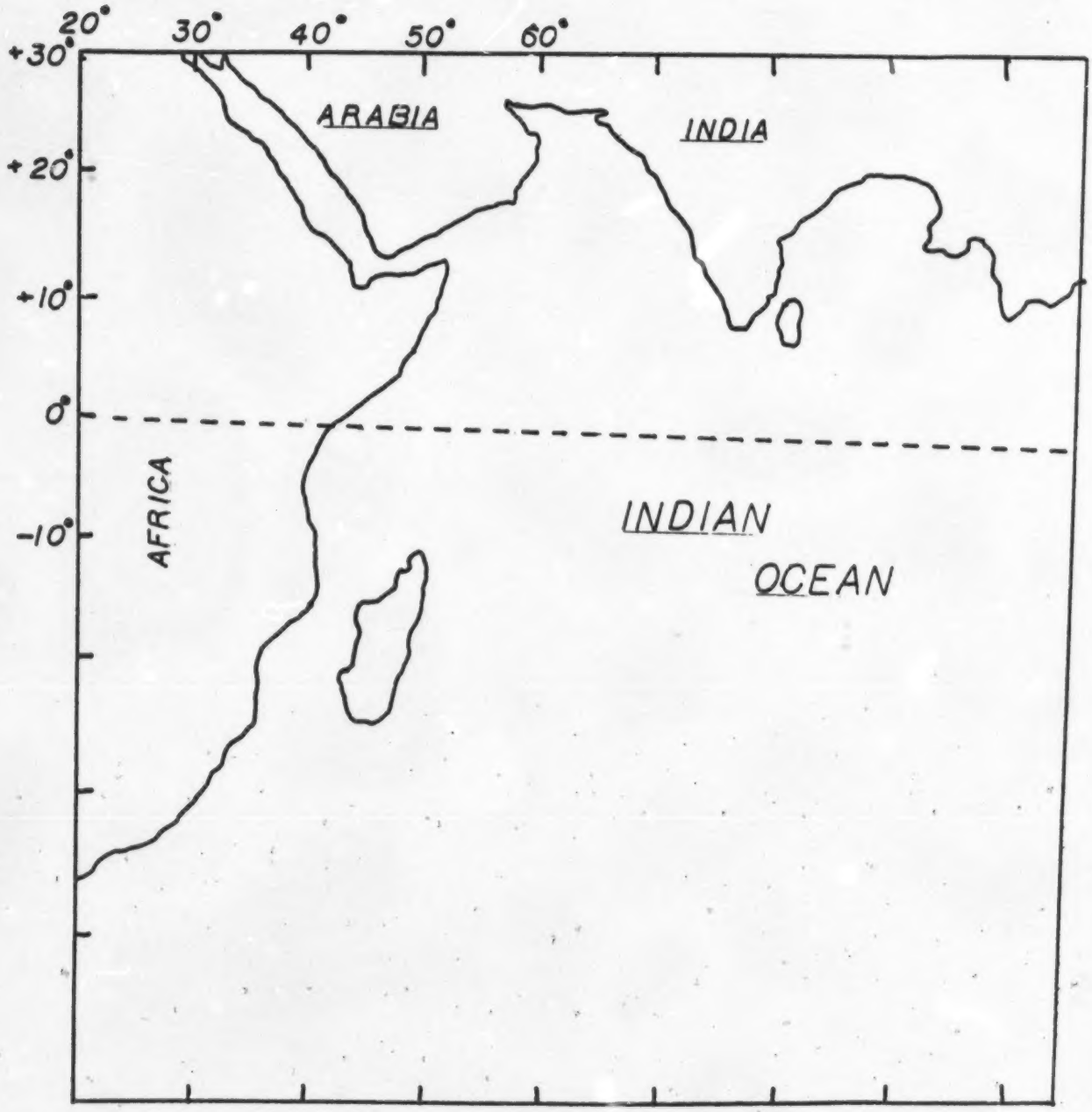
20N,38E	18N,39E
17N,40E	12N,41E
13N,42E	13N,46E
15N,52E	10N,38E
9N,37E	7N,35E
4S,35E	8S,39E

11. Mark the approximate location of plates 361 and 359 on the map (observe the base map carefully), by placing an "X" on worksheet 1.

12. How did the locations of the lineations and volcanoes compare with the earthquakes plotted?

13. What other type of evidence can you see on worksheet 1 that supports rifting around the Red Sea and the areas you observed with Landsat?

14. Do you think that a new rift zone is forming in east Africa? Explain.



WORKSHEET 1

15. In what ways does the rift zone observed in this activity compare to other rift zones such as the Mid-Atlantic Ridge and East Pacific Rise?

The earth is continually changing its face. The process of plate tectonics moves the crustal plates about, as forces of weathering and erosion break down mountains and carve valleys. In this lesson you have seen but a small part of a much larger process. Albert Einstein said: "As a circle of light gets larger, so does the circumference of darkness around it." The more we learn about the processes that shape the earth, the more we begin to wonder about our universe.

Review Questions

1. What type of movement of crustal plates formed the Red Sea?

2. The down dropping of a section of crust due to normal faulting is called a _____.

3. State three pieces of evidence to support the existence of a new rift zone in east Africa.

Plate Tectonics in the Solar System?
Evidence from Space Photography

by
Randy Allen, 1979

Introduction

The planet Earth is a unique body within our solar system; or is it?

Until recently, there had been little scientific data to suggest that any of the tectonic processes which take place here on earth, occur anywhere else in the solar system. However, with the advent of modern space technology, a whole new picture of our solar system is evolving.

Recent data collected by the NASA space missions indicates that the processes involved in plate tectonics may have occurred, or may be occuring on other bodies within our solar system. Some of the features that suggest tectonic activity are:

1. The presence of rift zones and faults indicating "planetquakes", which could signify movement of the body's upper surfaces.

2. The existence of high mountain ranges which could have been formed by segments of the planet's crust colliding into one another.

3. The presence of volcanoes, some of which are still active today.

But what does all this mean to you?

If we compare the tectonic processes occurring on other planetary bodies with those occurring on Earth, perhaps we can find a common link that will help us to better understand the Earth on which we live.

Objectives

After completing this activity, you should be able to:

1. Identify volcanoes and faults on high altitude imagery of the earth's surface and other planets.

2. Compare the tectonic activity of Ganymede, Io and the moon to that of the Earth.

3. Suggest a hypothesis to explain the similarities between the terrestrial planets.

Materials (see resources for complete references)

Mission to Earth: Landsat Views the World
Apollo Over the Moon: A View from Orbit (or photo of Kepler region)
Voyager to Jupiter (or photos of Ganymede and Io)
Images of Mars
Pencil

Part 1. Looking For Volcanoes.

The Earth certainly has volcanoes. How about other objects in the solar system?

1. Look at plate #376 in Mission . . . . The circular area in the center is a large volcano. What are the characteristics that distinguish it as a volcano?

2. Turn to plate #372. Find the volcano located at coordinates P-8. How is it similar to the first volcano you looked at?

3. Plate #322 contains an active volcano. Can you spot it? Give its co-ordinates _____. How can you tell that it is active?

4. On the back fly leaf of the book is a photo of the island of Hawaii. Would you say a volcano is present? _____. If so, describe the region you believe to be a volcano.

5. Look at the pictures of Ganymede and Io taken by Voyager I in Voyager. . . Look at them carefully. Is there any evidence of volcanoes or volcanic activity? _____. Describe any such findings.

6. How recent would you say the volcanic activity is on Io?

7. Do you now have enough information to say that plate tectonics does occur elsewhere? _____ Explain your answer.

Part 2. Looking For Faults. Do Other Bodies In The Solar System Have Faults?

Procedure

1. Examine plates #125, 126, and 129 in Mission . . . . These are all images of regions in California which contain large numbers of faults. By reading the description under each

photo, try to locate the major fault lines in each image. This takes some practice and you may require some help from your teacher on the first one.

2. Describe the characteristics of fault lines in the photos which enable you to pick them out.

3. Next, look closely at the pictures taken of Jupiter's largest moon, Ganymede in Voyager. . . .

4. What tectonic features do you find present on Ganymede?

5. Refer to photos of the lunar surface on pp. 199-209 of Appollo over the Moon (or photo of Kepler Region). See if you can locate any faults.

6. Compare the data from the moon with the data from Ganymede. How are they similar?

7. We have now seen that at least two signs of evidence for plate tectonics exist on other planetary bodies. Do you now have enough evidence to support a solar-system-wide plate tectonics theory? _____. What is lacking?

Part 3. The Last Step.

1. Using the sources listed in the "material" section determine which of the following planets and satellites (earth, moon, Ganymede, Io, Mars, Jupiter) have mountain ranges. Put this information in the data table.

Solar System Body	Faults	Volcanoes	Mountain Ranges
EARTH	yes	yes	yes
MOON	yes	yes	
MARS	yes	yes	
JUPITER	?	?	?
IO	yes	yes	
GANYMEDE	yes	yes	

DATA TABLE: Evidence of Plate Tectonic Activity on Bodies in the Solar System

2. By examining the data table, hypothesize as to whether or not plate tectonics is occurring on each of the planetary bodies, and fill in the rest of the table.

3. Is there a clear pattern developing? _____. If so, what is it?

4. Is the data presented here enough to support a theory of plate tectonics on a solar system-wide basis? Why or why not?

SUMMARY

In doing this activity, you should have found that there is good reason to believe that tectonic activity does occur elsewhere in the solar system; but not enough information has been obtained to definitely state that it is the common link between the planets. Even as you read this sentence, more data on this subject is being gathered by NASA spacecraft. The answers we seek could come tomorrow, next week, or never. For the time being however, we must be content with theorizing.

SUMMARY QUESTIONS

1. Is the Earth as "unique" as we once had thought? _____. Explain.

2. From what you have found in this activity, can you say that plate tectonics is definitely taking place on other planetary bodies? _____.

3. From your information could you hypothesize that plate tectonics is occurring on other planetary bodies? _____.

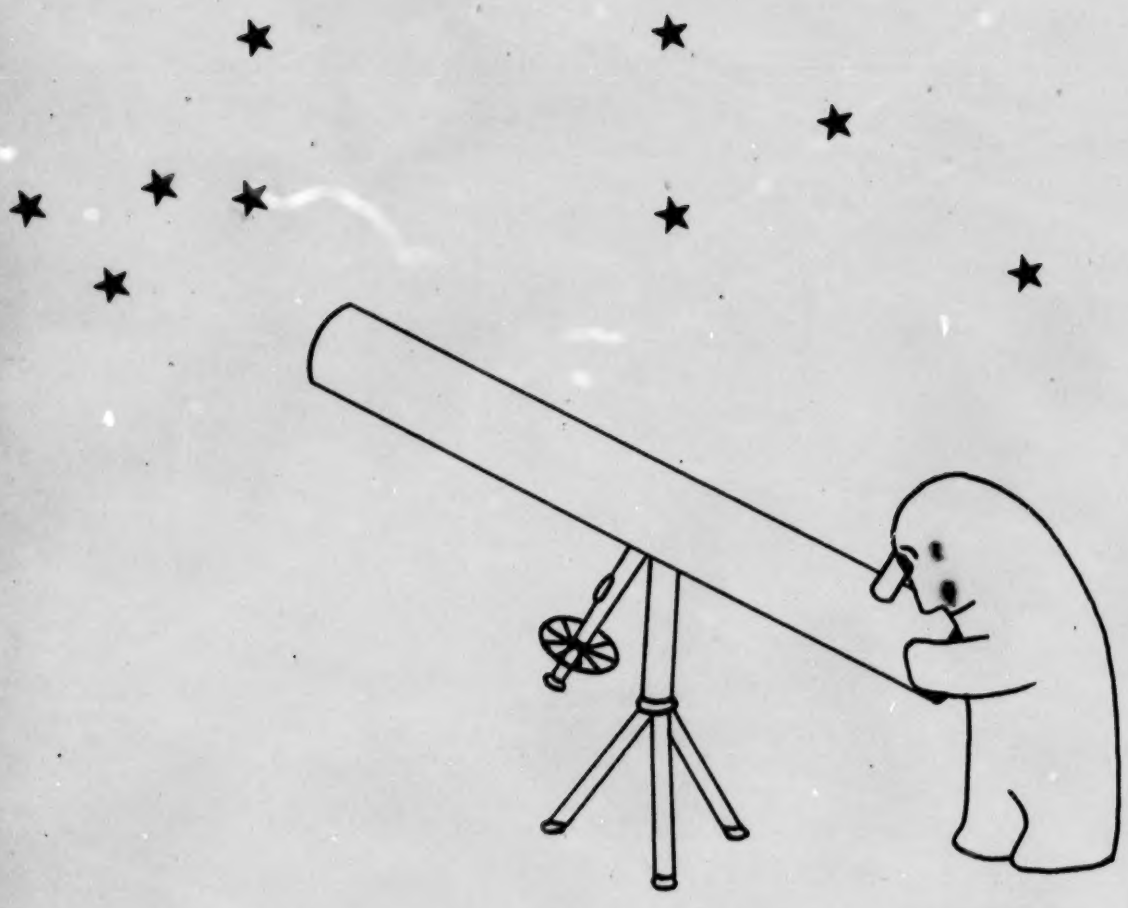
EXTENSIONS

1. If it could be proven that plate tectonics is a common link between the planets, what do you think this could tell us about Earth's beginning, past, and future?

2. There is a theory on the rise in the scientific community that suggests the terrestrial planets (Mercury, Venus, Earth, Moon, and Mars) are undergoing a process of planetary evolution. Use the evidence that you have gathered to support or argue against this theory. Also tell what such a theory could tell us about the earth.

CHAPTER VI

SPACE



Lost on the Moon:
A Decision-Making Problem

Adapted from a simulation developed
by National Aeronautics and Space
Administration, 411 East Capitol Street, S.E.
Washington, DC 20003

by
Robert A. Champlin

Introduction

You are in a space crew originally scheduled to rendezvous with a mother ship on the lighted surface of the moon. Mechanical difficulties, however, have forced your ship to crash-land at a spot some 200 miles from the rendezvous point. The rough landing damaged much of the equipment aboard. Since survival depends on reaching the mothership, the most critical items available must be chosen for the 200 mile trip. On the next page are listed the 15 items left intact after landing. Your task is to rank them in terms of their importance to your crew in its attempt to reach the rendezvous point.

Objectives

After you have completed this activity you should be able to:

1. Write an essay or give an oral report about conditions on the lunar surface.

2. Formulate a logical "survival plan" for any space travelers lost on the moon.

Procedures

1. Using the references listed at the end of this activity and any other suitable material, write a report about the conditions of the lunar surface and what might be expected to affect the survival expedition in terms of radiation, light intensity, meteor showers, and gravitational effects. This research will be your only available information on which you may base your final decisions, so do well. Your life on the moon will depend upon it!

2. **Rank in the order of importance:**

a. ---box of matches
b. ---food concentrate
c. ---50 feet of nylon rope
d. ---parachute silk
e. ---portable heating units
f. ---two .45 caliber pistols
g. ---one case dehydrated milk
h. ---two 100 pound tanks of oxygen
i. ---stellar map including the moon's constellations
j. ---life raft
k. ---magnetic compass
l. ---5 gallons of water
m. ---signal flares
n. ---first-aid kit with injection needles
o. ---solar-powered FM receiver-transmitter

Scoring Key: If this is done as a game, the score can be determined by the difference between the number assigned and the suggested numbers assigned below. Low score wins.

(15)	*box of matches*	*little or no use on moon, no available oxygen*
(4)	*food concentrate*	*supply daily food required*
(6)	*50 feet of nylon rope*	*useful in tying injured, help in climbing*
(8)	*parachute silk*	*shelter against sun's rays*
(13)	*portable heating unit*	*useful only if party landed on dark side*
(11)	*two .45 caliber pistols*	*self-propulsion devices*
(12)	*one case dehydrated milk*	*food, mixed with water for drinking*
(1)	*two 100 pound tanks of oxygen*	*fills respiration requirement*
(3)	*stellar map (of the moon's constellations)*	*principal means of finding directions*
(9)	*life raft*	*CO_2 bottles for self-propulsion across chasms, etc.*

(14)	*magnetic compass*	*probably no magnetized poles; thus of no use*
(2)	*5 gallons of water*	*replenishes loss by sweating, etc.*
(10)	*signal flares*	*distress call within line of sight*
(7)	*first-aid kit*	*oral pills or injection medicine may be valuable*
(5)	*solar-powered FM receiver-transmitter*	*distress signal transmitter possible communication with mother ship*

References

Moore, Patrick. New Guide to the Moon. W. W. Norton and Co. Inc. New York, 1976.

Wood, John A. "The Moon" Scientific American, Vol. 233:92, September, 1975.

Observation of Sunspots

by
Robert A. Champlin
and
Glenn Chaple

Introduction

One of the interesting aspects of the sun is the appearance of sunspots (thought to be solar storms). Astronomers spend a great deal of time studying sunspots in the hope of understanding why they occur and what, if any, effect they have on the earth. In this activity you will make observations about sunspots that a typical scientist might make.

Objectives

When you have completed this activity you should be able to:

1. Make a meaningful statement about sunspot patterns.

2. Determine at least one behavior pattern of the sun.

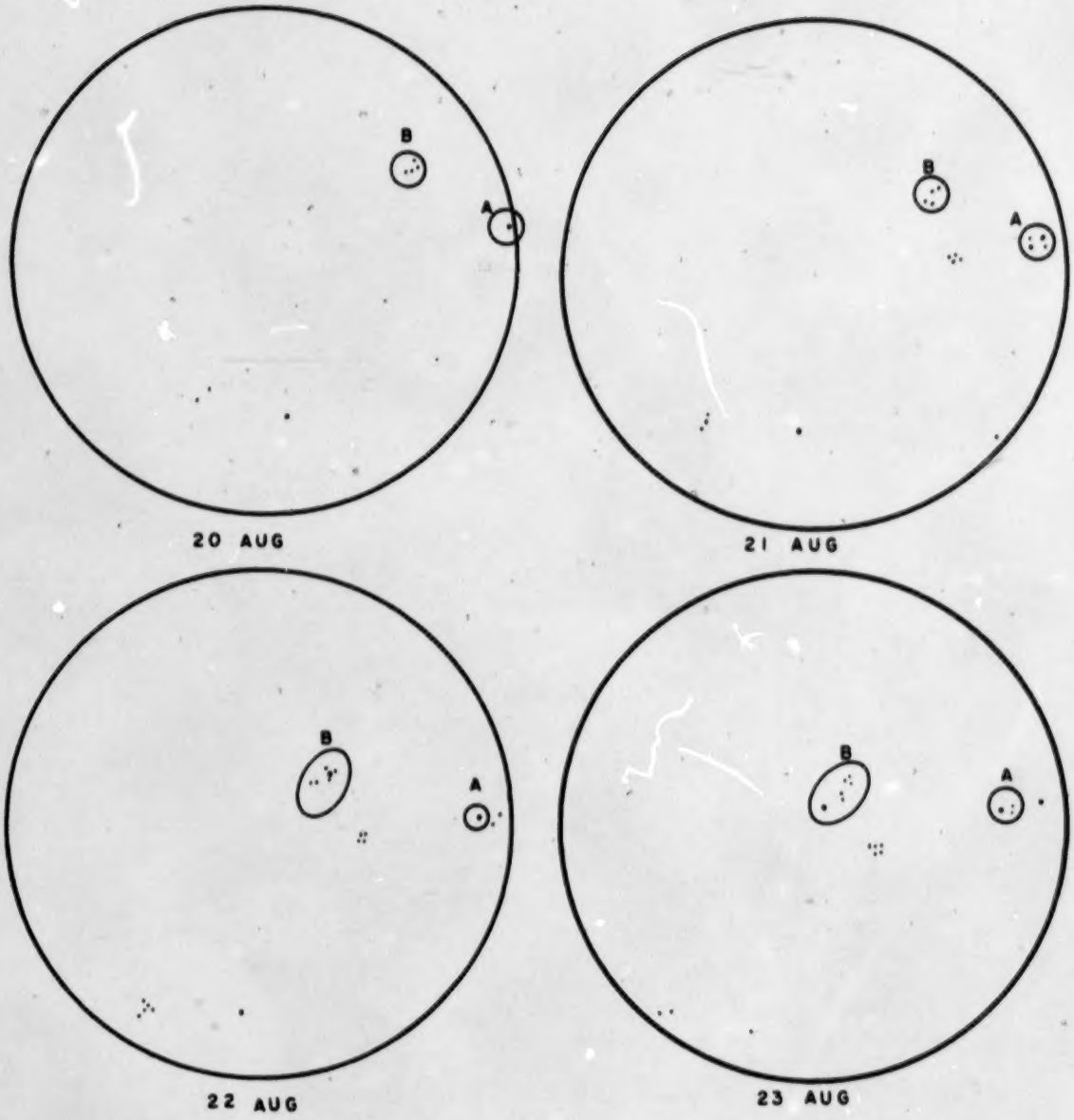
Materials

Sunspot charts

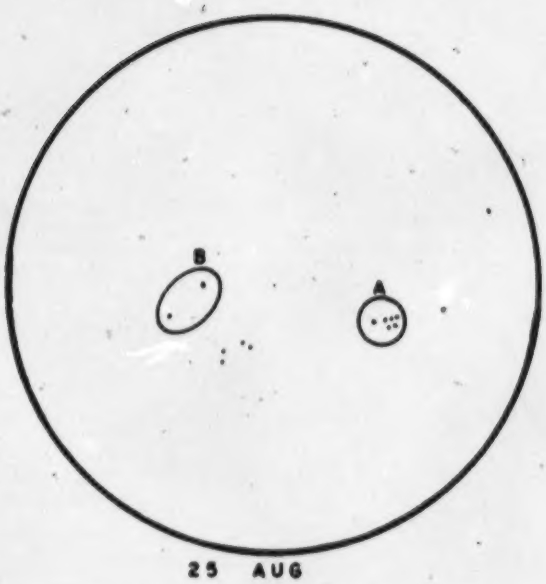
Procedure

The next three pages contain the reproduction of a series of sketches of the sun as they were drawn by Glenn Chaple, a staff member of the Alice G. Wallace Planetarium. From August 20 to September 1, 1972 he made daily observations, sketching the sun as it appeared when viewed through a 2.4-inch refracting-type telescope at 30X magnification.* Each sketch shows the sun and the positions of sunspots as viewed that day. Observations for August 24th and 27th were not made because of cloudy skies.

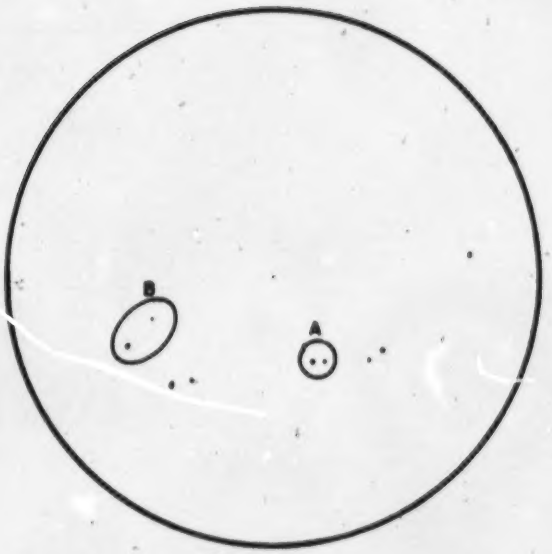
*WARNING: It is very dangerous to view the sun directly through a telescope without special protective equipment. The blinding light and heat energy of the sun, along with harmful amounts of ultraviolet and infrared radiation, can cause serious damage to the retina of the eye- and eventual blindness-in just a fraction of a second. For his observations of the sun, Mr. Chaple placed a specially-made sun filter in the eyepiece of the telescope. The filter served to block out most of the solar radiation, making the sun safe for viewing. Unless your own telescope has such a filter, NEVER use it to look directly at the sun.



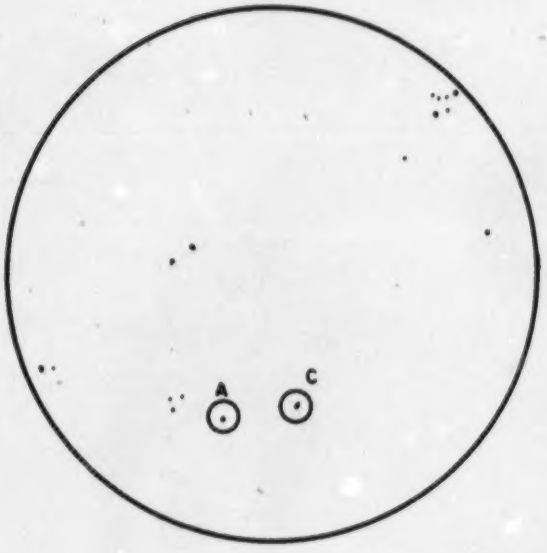
229



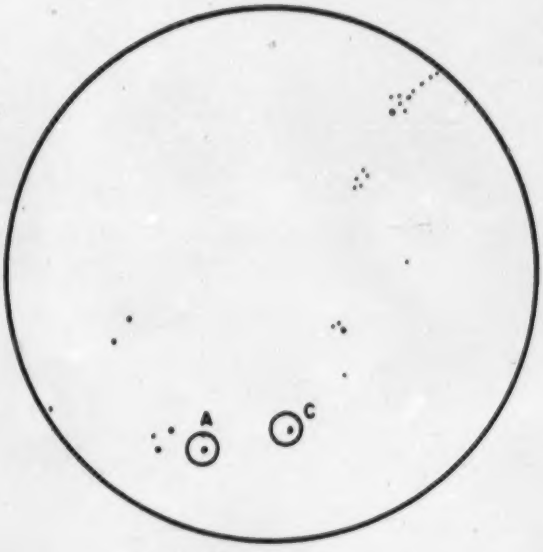
25 AUG



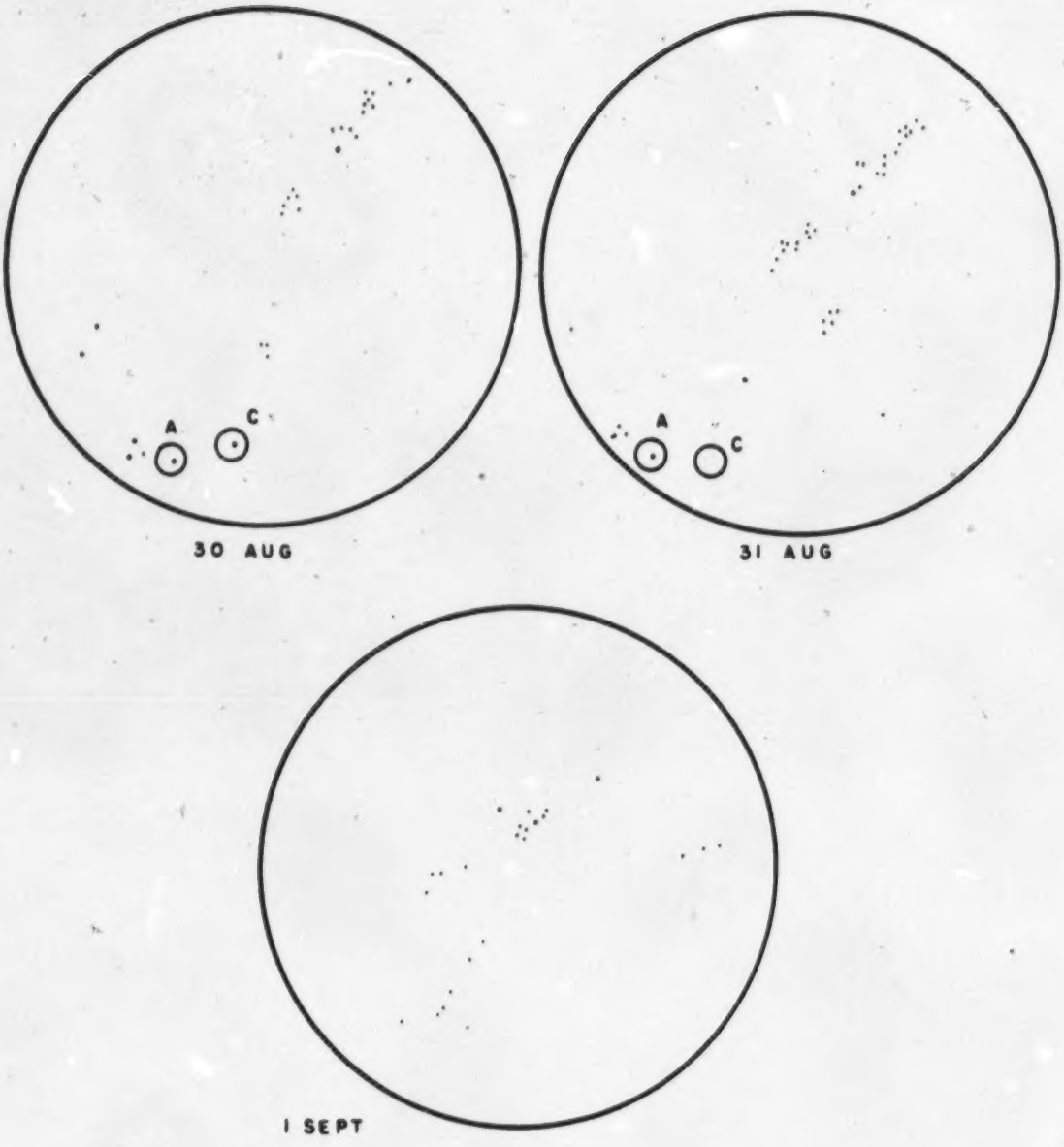
26 AUG



28 AUG



29 AUG



231

Scan through the sketches of the sun in the order of the dates the observations were made. Close attention should be given to the circled groups marked A, B, and C to notice any pattern or relationship in the positions and spacing of the sunspots from day to day. Once you have determined these patterns and relationships, return to this section and answer the questions below.

1. What reasons can you give for the changing day to day appearance of the sun and sunspots?

2. Look at sunspot group A. Describe what happened to this group from day to day and what this observation might indicate about the sun.

3. Notice the location of group A on August 20. After how many days will it again be observed in that position?

4. Describe what happened to sunspot group B and what this might tell us about sunspots.

5. Describe what happened to sunspot group C and what this might tell us about sunspots.

6. Astronomers around the world keep a daily record of the number of sunspots visible on the sun. What is the sunspot count on August 20? September 17?

The Parallax Effect

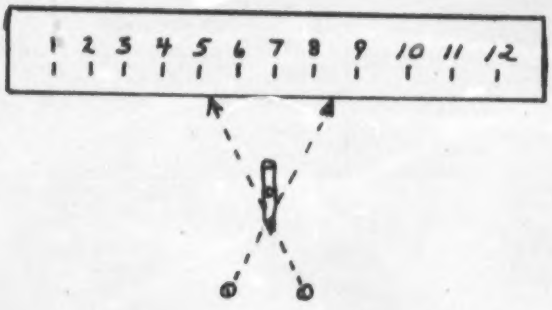
Adapted from The University of Illinois
Astronomy Project, Book 1: Charting the Universe,
Harper and Ross Publishers, 1969

by
Robert Champlin

Introduction

You often use an indirect method to measure distances, although you may not be aware of it. Each time you look across the room and say what is closest to you and what is farthest away, you use this method. The basic idea can be demonstrated simply. Hold a pencil in front of you at arm's length and look at it with one eye. Now, without moving the pencil or your head, look at it with your other eye. Notice that the pencil appears to move against the background of the wall beyond.

This apparent change of position against background objects is called the parallax effect or more simply, parallax. Parallax is the basis for the indirect method by which you estimate distances.



Objectives

As a result of completing this activity you should be able to:

1. Measure the parallax of various objects in the classroom.
2. Be able to accurately state several facts about parallax.
3. Use the parallax effect to measure distances to objects.
4. Make a crude map of the school grounds using the parallax technique.

Materials

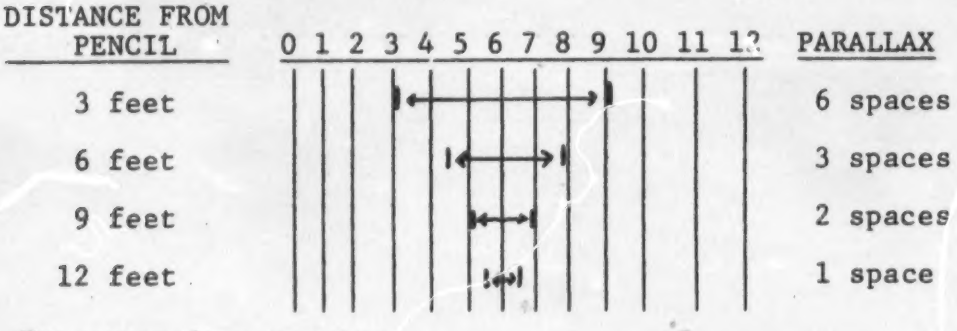
Piece of cardboard or stiff construction paper
A Protractor
Pencil and paper

Procedure

Part 1

How does the parallax change as the distance to the object changes? For this investigation, put a series of equally separated lines on the chalkboard. Number them in order. We shall call the parallax the change in position of the object as seen against these lines as a background. For example, if the position of the pencil is 2 as seen with your right eye and 7 as seen with your left, this is a parallax of 5 (7 - 2 = 5). (You may want to divide the chalkmarks further to make more precise measurements--to measure a parallax of 5 1/2, for example).

Have a friend hold up a pencil for you to determine the parallax for several distances as you move away from your friend. Be sure your friend stays in the same place while you move back. Keep your record on a chart like this.



Now answer these questions.

1. Does parallax get larger or smaller as the distance increases?

2. Is there a distance at which you no longer see any parallax?

As you look at things with your two eyes, your brain estimates parallaxes automatically. This is one way you can tell which objects are near you and which are far away. (You use other methods, too.) A small parallax indicates a more distant object; a large parallax indicates a closer object.

Without parallax, you can't easily judge distance, even to close objects. To demonstrate the idea for yourself, try this. Hold a pencil in each hand. Close one eye and try to touch the ends of the pencils together. What happens?

You have now demonstrated two basic ideas about parallaxes:

A. Two positions are needed from which to sight (in this case, your two eyes).

B. The parallax effect is smaller as the object is moved farther away.

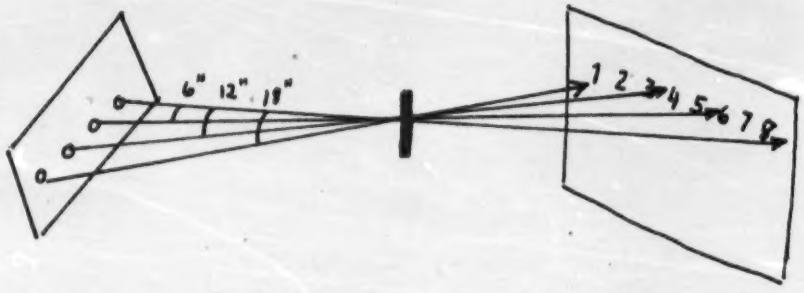
Part 2

How would parallax change if your eyes were further apart?

Get a piece of cardboard or stiff construction paper. Punch small holes in it in a straight line. Make the holes six inches apart.

Have a friend hold the paper directly in front of you. Perhaps you can fix up a support to hold it in place, since you do not want it to change during the activity. Sight through the first hole at a pencil held by another friend. Then sight through the second hole. Record the parallax. Now record the parallax using only your eyes, without the paper.

Notice that the first time the separation of your sighting positions is 6 inches; the second time, 12 inches; the third time, 18 inches.

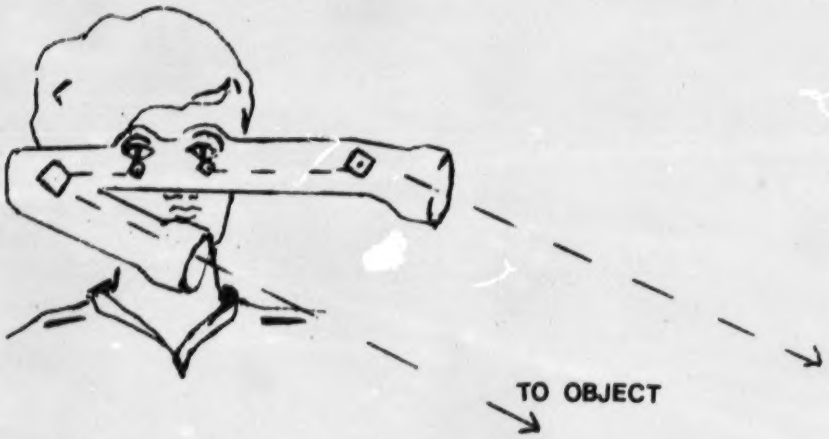


Base Line	Parallax
3 inches (eyes)	
6 inches	
12 inches	
18 inches	
24 inches	

What conclusions can you draw from this table?

The separation between the two sighting positions--between two of the holes or between your two eyes--is called the base line. The activity shows that when your base line is longer, the parallax is greater. Can you imagine also that with a longer base line, you could see the parallax of an object farther away? Also, the parallax measured with a longer base line is more accurate because it is easier to measure large changes in position than small changes.

Perhaps you have seen pictures of range finders used in the military services. These devices are artificial ways of making the eyes seem further apart. With a longer base line, a person measures greater distances.

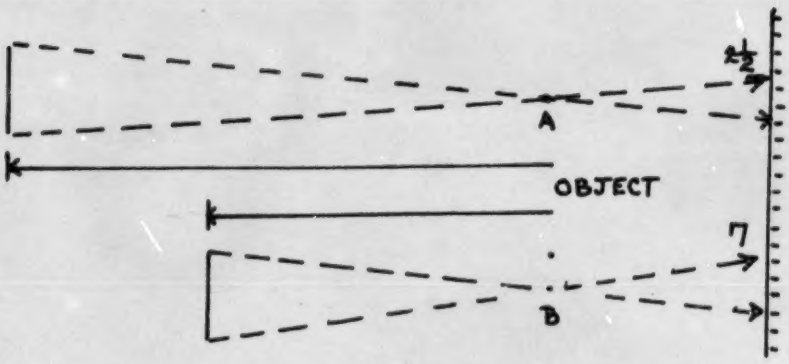


You now know two more basic ideas about parallax.

C. The longer the base line, the larger the parallax effect.

D. The longer the base line, the greater the distance at which the parallax effect may be seen.

Think again of the first activity you did on parallaxes. You observed that the parallax becomes smaller as the distance becomes larger. Here is a diagram which shows the parallax for two different distances.



Look at the two sets of lines in this diagram. Notice that the lines cross at the pencil at different angles in the two cases.

Which set of lines crosses at the smaller angle?

Which pencil has the smaller parallax?

Which set of lines crosses at the larger angle?

Which pencil has the larger parallax?

As the parallax becomes smaller, the angle at which the lines intersect becomes smaller also. We call the angle of intersection the parallax angle. The answers to the above questions tell you something about parallax angles.

E. The larger the parallax, the larger the parallax angle.

F. The greater the distance, the smaller the parallax angle.

Since the parallax angle changes the same way the parallax does then,

G. The larger the base line, the larger the parallax angle.

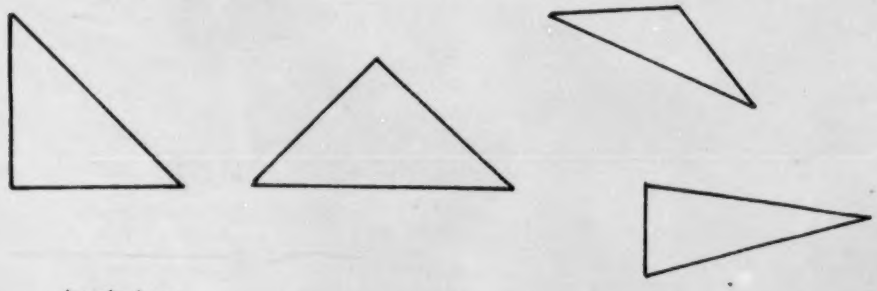
Part 3. Using The Parallax Effect.

You now know several basic ideas about the parallax effect and parallax angles. One important idea is this. When you use a certain base line, the farther away an object is, the smaller the parallax angle. This is the basis for measurement of distances in space. The idea is also used by surveyors when they determine distances and cannot use direct measurement.

The procedure works something like this. A base line of known length is set up. From opposite ends of this base line you sight at some distant object. From the object's change in position against the background you determine its parallax or parallax angle. Knowing the parallax angle and the length of the base line you can determine the distance.

But exactly how do we measure the parallax angle? And how does that really tell us the distance to the object? Let's see how you figure out the size of a parallax angle without going there to measure it.

To understand the procedure you must first learn something about triangles. A triangle is a figure with three angles. It also has three sides. Here are some triangles.



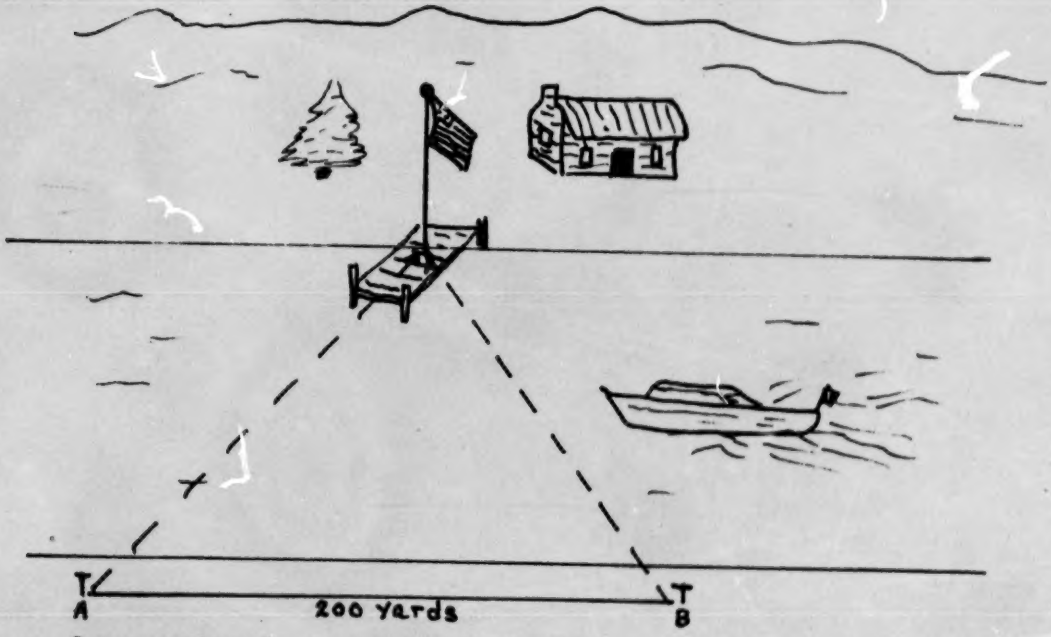
Activity

Try drawing some triangles on paper. With your protractor, measure the size of each angle. Add up the sizes of the angles in each triangle you draw. Do you get the same answer for each triangle? You should. The angles in every triangle add up to 180 degrees.

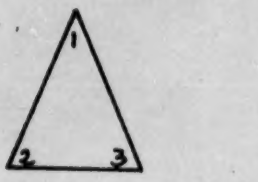
Let us see how this fact about triangles helps a surveyor measure the distance across a river. In our picture we have a surveyor on one side of the river with a flagpole on the other side. The surveyor's problem is to measure the distance to that flagpole.

The surveyor first needs a base line from which to make his observations. Suppose he sets up a base line 200 yards long and puts a stake at each end. Then from one end of the base line (position A) he sights first at the flagpole and then at the stake at the other end of the base line. Now he knows the angle between these two directions. Next he walks to the other end of the base line and does the same thing again.

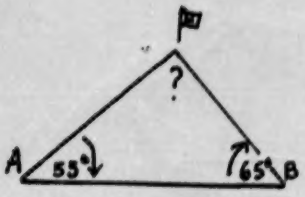
Notice that he has now measured the size of two angles in a triangle. The triangle includes the flagpole and the two ends of the base line.



Suppose that from position A the surveyor finds an angle of 55 degrees between the flagpole and position B. When he goes to position B and looks back, he finds an angle of 65 degrees between position A and the flagpole. Look at the diagram. Can you see that these measurements also tell us the angle at the flagpole (our parallax angle)? It must be 60 degrees. Do you see how?



$1 + 2 + 3 = 180°$



To make a scale drawing of this triangle, use a baseline of two inches. On a sheet of paper, make this triangle with the correct angle sizes. Now you can measure on this triangle and determine what the true distances really are. Two inches equal 200 yards. Therefore 1 inch is 100 yards. One-half inch is 50 yards. On your scale drawing, measure the distance from each end of the base line to the flagpole. Measure the shortest distance from the base line to the flagpole. Change your measurements back into yards.

For practice, try being the surveyor in these problems. Use scale drawings.

1. A surveyor uses a base line 1 mile long. From one end of the base line he measures an angle of 75 degrees between the base line and a smoke stack across a lake. From the other end he finds an angle of 62 degrees. What is the parallax angle? What is the distance from the first point to the smoke stack?

2. With a base line of ten feet, the well-known Asmonia surveyor, Fido Phump, finds angles of 80 degrees and 60 degrees as he looks at a flagpole from either end of his base line. How far is he from the flagpole?

Part 4. The Moon's Distance.

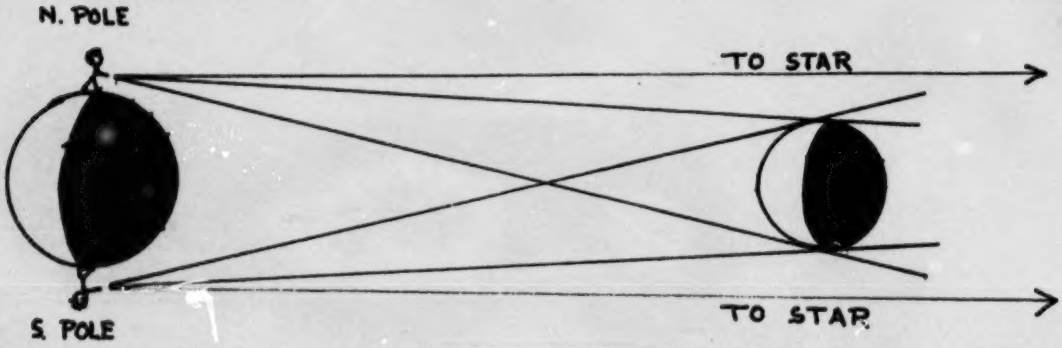
The distance to the moon was first learned by using the parallax effect. The parallax angle for the moon is the angle made when we draw two lines from opposite ends of a base line to the moon. We measure this angle by observing the moon's position against the distant stars.

In the river example, the surveyor used a base line 200 yards long. If the river were much wider, he would have used a longer base line.

For measuring astronomical distances, long base lines are needed. The objects are very far away. A base line 200 yards long--or even a hundred miles long--is too short because the parallax angle is not large enough to be measured. To find the distance to the moon, our nearest big neighbor in space, a base line which is thousands of miles long is necessary.

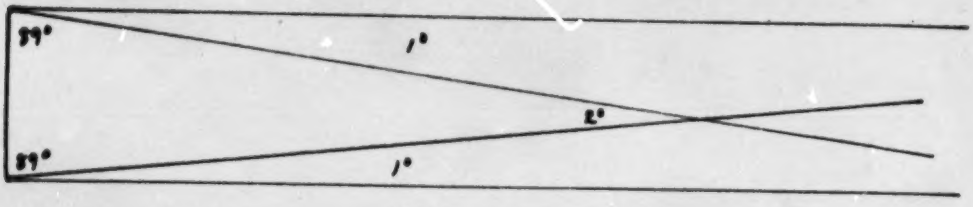
You may now be asking, "How do we measure the parallax angle for the moon?" Let's see. In the sky we see the moon against a background of stars. Any single star is so far away that it appears in the same direction in space no matter where we see it from the earth. This is because any base line on the earth is so small. The actual difference in direction to this star is much too small to be measured.

Now let's think about a special example. Suppose you are at the north pole and you have a friend at the south pole. So the horizon won't interfere with your observations, you had both better climb to the top of a tall tower. While shivering, you both point at a certain star that you both can see. You are both then pointing in the same direction. The picture shows you and your friend pointing to this star. On this diagram, the angle between the star and the earth's diameter is 90 degrees for each of you.

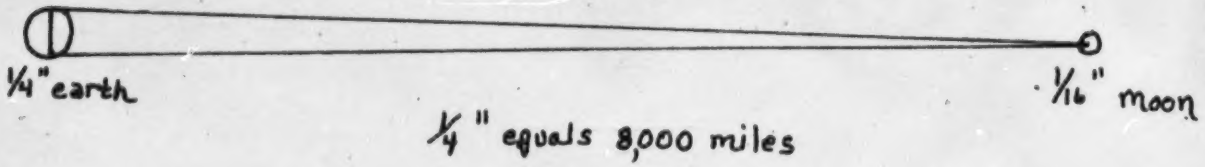


Suppose you both point to the moon. Now you no longer point in the same direction as your friend. Next each of you measures the angle between the direction to the moon and the direction to the star. You each get an angle of about one degree.

Here is the picture. The angle between the earth's diameter and the direction to the star for you is 90 degrees. The angle between the moon's direction must be 89 degrees. The same thing works for your friend. These two angles of 89 degrees are two angles in a triangle. The remaining angle must be two degrees. Why? And this is exactly the parallax angle of the moon. The parallax angle for the moon is 2 degrees with a base line of 8000 miles. With a scale drawing you can now figure out the distance to the moon.



Using a protractor, draw an angle of 2°. Do this as carefully as you can. Find where the lines are a quarter-inch apart. Let this one-quarter inch represent the diameter of the earth, 8000 miles. What do you get for the distance to the moon?



1/4" equals 8,000 miles

An early measurement of the moon's parallax was made in 1752. Two observatories were set up. One was in Germany,

and the other was in South Africa. This gave astronomers a base line of about 5000 miles. The observations of the moon's position among the stars gave the parallax angle of the moon, and thus its distance. They found that the moon is 240,000 miles away!

Radar can now be used to measure the distance to the moon. A radar set sends out a radio signal which bounces off an object. The return echo is received by the radar set. Radio signals travel at the speed of light, which is 186,000 miles per second. The U.S. Army Signal Corps sent a radio signal to the moon and received the echo in about 2.6 seconds. Remembering that this is the time for a round trip, can you figure out the distance to the moon as determined by radar?

Radar methods can also be used for a few of the closer planets in the solar system. But remember that distances within the solar system had been measured long before radar was invented.

Star Color and Composition

Adapted from an activity
Developed by National Aeronautics
and Atmospheric Administration

by
Victor J. Mayer

Objectives

When you have completed this activity you should be able to:

1. Tell how the color of a star is related to its temperature.
2. Tell how astronomers identify the materials in the sun or a star.
3. Explain how to build a spectroscope.

Procedure

Part A

The color of stars depend upon the temperature and material of which the stars are made. Generally, red stars are cooler than yellow stars, and yellow stars are cooler than white stars.

1. Use a burner to heat a piece of iron wire. This wire can be obtained from the hardware store or variety store as picture hanging wire.
2. Increase the temperature and note the change in colors. For good viewing, this is best done in a semi-darkened room.

Part B

When a material is heated to the point of radiating energy in the form of light, this energy is peculiar to that material. The light we see coming from burning coal is

different from that of a burning match. However, this radiating energy does not always appear different to our unaided eye.

Scientists have developed an instrument called a spectroscope which enables them to distinguish between the colors of radiating matter. A spectroscope attached to a telescope enables a scientist to look at a star and determine what materials are radiating the light.

Materials

A small replica grating (this may be called a diffraction grating in some of the catalogues of the scientific supply houses.) *Make sure you do not spoil the grating by touching it with your fingers.* Source: Edmund Scientific Company, Barrington, New Jersey.

A shoe box, or a large candy box that has one long dimension

Two single-edged razor blades

An alcohol lamp, or a propane burner, or a candle

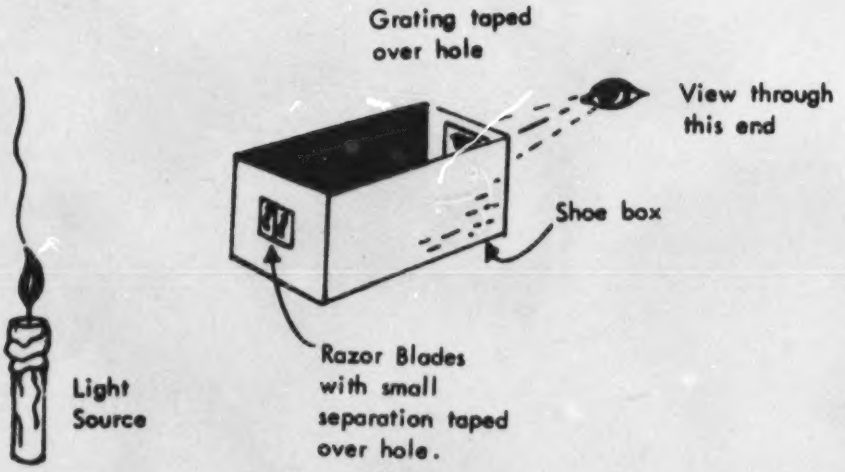
Table salt, epsom salts, baking powder, sugar, a variety of salts obtained from your local drug store.

Cut a very thin vertical slit in the middle of one end of the box. In the other end of the box cut a hole just a tiny bit smaller than your piece of diffraction grating.

Tape the diffraction grating over the larger hole. Tape the two razor blades over the slit so that the edges of the blade may be squeezed together to form an extremely narrow and sharp slit.

Hold the grating to your eye and aim the slit toward an incandescent light. You should see a beautiful spectrum of colors on each side of the slit on the inside of the box. If your spectrum is above and below the slit, untape your grating and rotate it 90° and then retape it to the box. Look again.

While you are looking in your spectroscope, have someone sprinkle a little of each of several chemicals in a flame from your heat source. Can you see the bright line fingerprints of each chemical? In most materials you will see a bright orange line. The line shows the presence of sodium which is abundantly present in the compound of table salt (sodium chloride).



From an encyclopedia or other available source, gather some pictures of spectra of a variety of materials. Using your spectroscope, compare these spectra with those you see of the same materials. Remember that the spectroscope used in commercial and astronomical work is an extremely sensitive and expensive apparatus. This will account for many noticeable differences in the picture of spectra and the spectra you observe.

Use your spectroscope in examining many kinds of lights including fluorescent lights, and "neon" lights. Neon lights glow with a variety of colors because of the presence of different gases in the tubes.

Part C

Read about the different star types and discuss how the astronomers know their contents.

Part D

Obtain Fourth of July sparklers which burn with a variety of colors.

Classify sparklers by identifying the colors with which they burn.

Obtain a variety of materials that are used to produce colors in a fireplace.

Burn several pieces of this material and observe the colors with which the materials burn.

Plotting an H-R Diagram

by
Glenn Chaple

Introduction

The Hertzsprung-Russell (H-R) diagram is a convenient way of classifying stars by temperature and brightness. It shows the relationship between spectral class, color, temperature, absolute magnitude, and luminosity.

Objectives

When you have completed this exercise you should be able to:

1. Accurately plot a graph requiring two variables per point.
2. Read the data from an H-R diagram and answer simple questions concerning the information shown.
3. Determine several relationships between the temperature, brightness, spectral class, color and absolute magnitude of various stars.

Materials

A pen and pencil
A chart entitled THE BRIGHTEST STARS and THE NEAREST STARS

Procedure

Begin your H-R Diagram by plotting in pencil the stars from the "Brightest Stars" list. Work carefully to avoid mistakes. When finished, plot in pen the stars from the "Nearest Stars" list. Whe you have completed all plots, answer the questions on this page.

1. Which spectral class of stars is the most common?
2. Which spectral class is the least common?
3. Which kind of star tends to be the brighter - an M-type star or a B-type star?
4. What is the relationship between the temperature of a star and its brightness?

5. On your H-R diagram, label the following groups: Main Sequence Stars, Giants and Super-giants, White Dwarfs.

6. Relocate your plot of the sun and circle it in pencil. To which of the above three groups (#5) does the sun belong?

7. Since stars of the same spectral class and brightness as our sun might contain earth-like planets, they may be important to future explorers. Name a star from your list that might be worth exploring, because it is similar to the sun.

8. Which list (Bright Stars or Nearest Stars) offers a more random star sample?

247

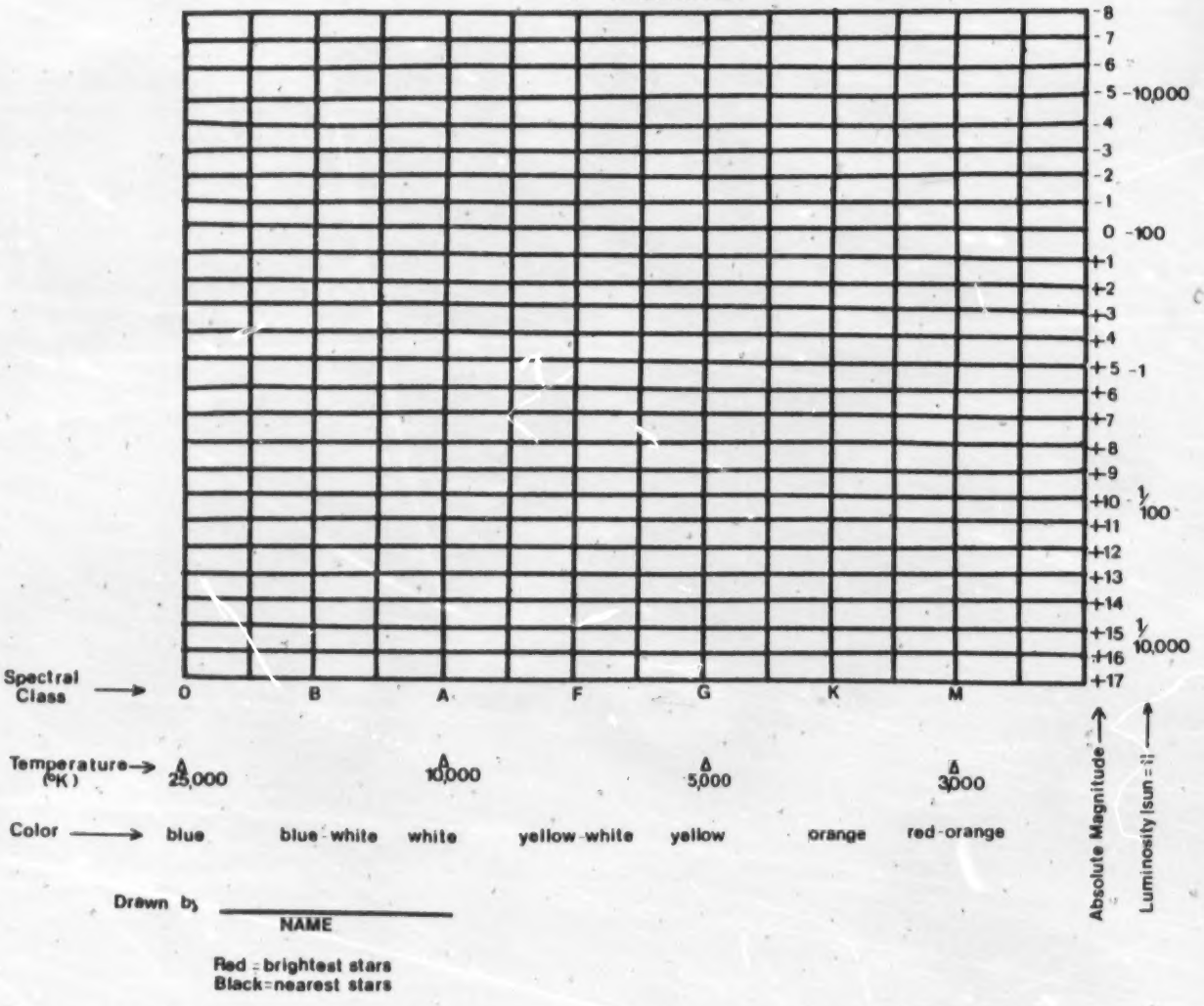
THE BRIGHTEST STARS

	STAR	SPEC.	M.abs.
1.	SIRIUS A	A1	+1.4
	B	B8	+11.5
2.	CANOPUS	F0	-3.1
3.	-CENTAURI A	G2	+4.4
	B	K5	+5.8
4.	ARCTURUS	K2	-0.3
5.	VEGA	A0	+0.5
6.	CAPELLA A	G0	-0.7
	B	M0	+9.5
	C	M5	+13.0
7.	RIGEL A	B8	-6.8
	B	B9	-0.4
8.	PROCYON A	F5	+2.7
	B	F0	+13.0
9.	ACHERNAR	B5	-1.0
10.	B CENTAURI	B11	-4.1
11.	BETELGEUSE	M2	-5.5
12.	ALTAIR	A7	+2.2
13.	ALDEBARAN A	K5	-0.2
	B	M2	+12.0
14.	-CRUCIS A	B1	-4.0
	B	B3	-3.5
15.	ANTARES A	M1	-4.5
	B	B4	-0.3
16.	SPICA	B1	-3.6
17.	POLLUX	K0	+0.8
18.	FOMALHAUT A	A3	+2.0
	B	K4	+7.3
19.	DENEB	A2	-6.9
20.	B CRUCIS	B0	-4.6
21.	REGULUS	B7	-0.7
22.	ADHARA	B2	-5.0
23.	CASTOR A	A1	+2.1
	B	A5	+2.9
	C	K6	+8.8
24.	SHAULA	B1	-3.3
25.	BELLATRIX	B2	-4.2

THE NEAREST STARS

	STAR	SPEC.	M.abs.
1.	The Sun	G2	+4.8
2.	-Centauri A	G2	+4.4
	B	K5	+5.8
	C	M5	+15.0
3.	Barnard's Star	M5	+13.2
4.	Wolf 359	M6	+16.8
5.	Lalande 21185	M2	+10.5
6.	Sirious A	A1	+1.4
	B	B8	+11.5
7.	Luyten 726 A	M5	+15.4
	B	M6	+15.8
8.	Ross 154	M4	+13.3
9.	Ross 248	M5	+14.7
10.	E. Eridani	K2	+6.1
11.	Luyten 789-6	M5	+14.7
12.	Ross 128	M5	+13.5
13.	61 Cygni A	K5	+7.5
	B	K7	+8.3
14.	E Indi	K5	+7.0
15.	Procyon A	F5	+2.7
	B	F0	+13.0
16.	Struve 2398 A	M4	+11.1
	B	M5	+11.9
17.	GROOM. 34 A	M1	+10.5
	B	M6	+13.2
18.	Lacaille 9352	M2	+9.6
19.	T Ceti	G8	+5.7
20.	BD+5° 1668	M4	+11.9
21.	Lacaille 8760	M0	+8.7
22.	Kapteyn's Star	M0	+8.7
23.	Krueger 60 A	M3	+11.8
	B	M4	+1[illegible]4
24.	Ross 614 A	M5	+13.[illegible]
	B		+16.8
25.	BD-12° 4523	M4	+12.0

H - R DIAGRAM



Drawn by _____
NAME

Red = brightest stars
Black = nearest stars